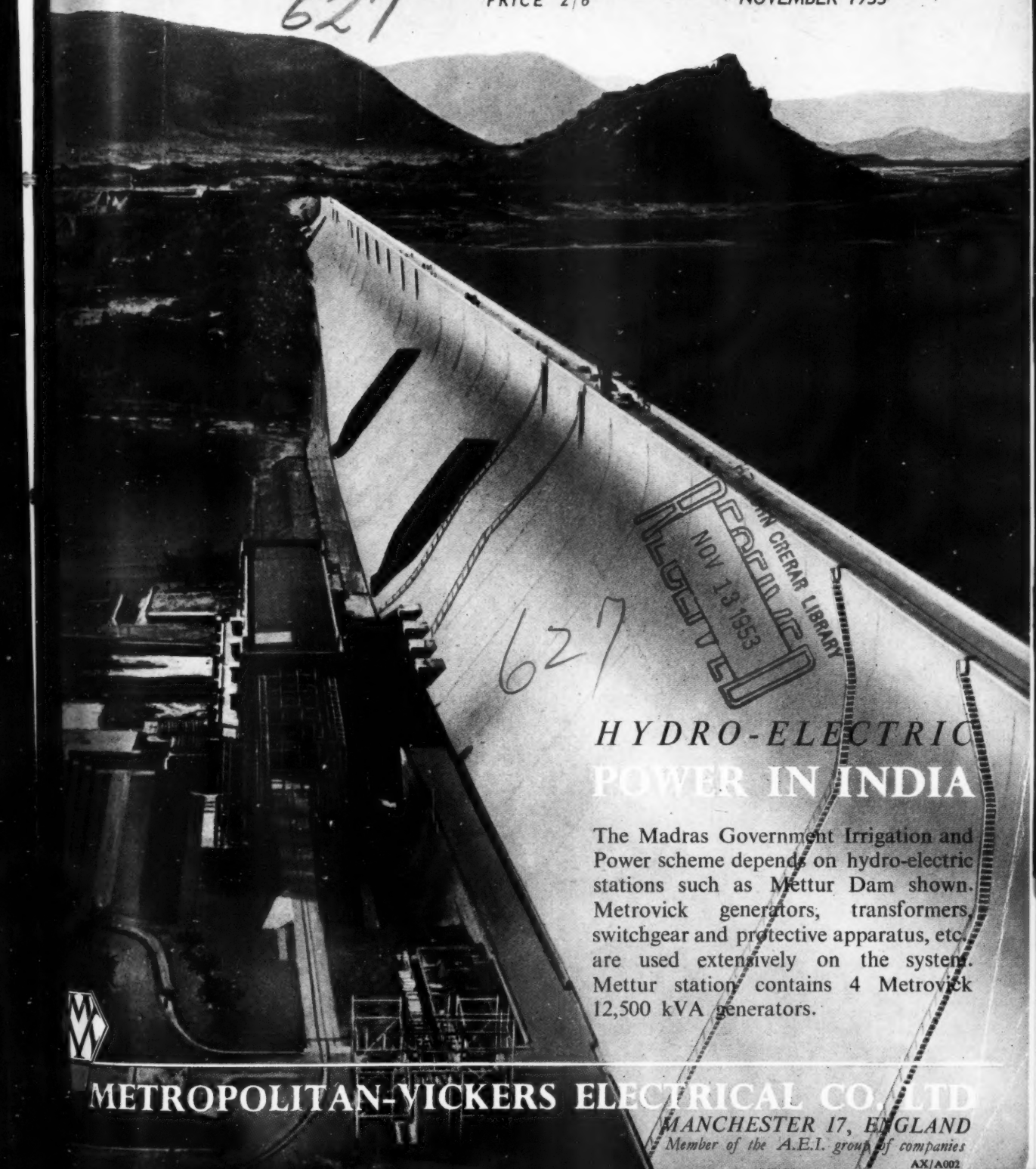
Water Power

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

627

PRICE 2/6 NOVEMBER 1953



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HYDRO-ELECTRIC
POWER IN INDIA

The Madras Government Irrigation and Power scheme depends on hydro-electric stations such as Mettur Dam shown. Metrovick generators, transformers, switchgear and protective apparatus, etc. are used extensively on the system. Mettur station contains 4 Metrovick 12,500 kVA generators.

METROPOLITAN-VICKERS ELECTRICAL CO. LTD
MANCHESTER 17, ENGLAND
A Member of the A.E.I. group of companies
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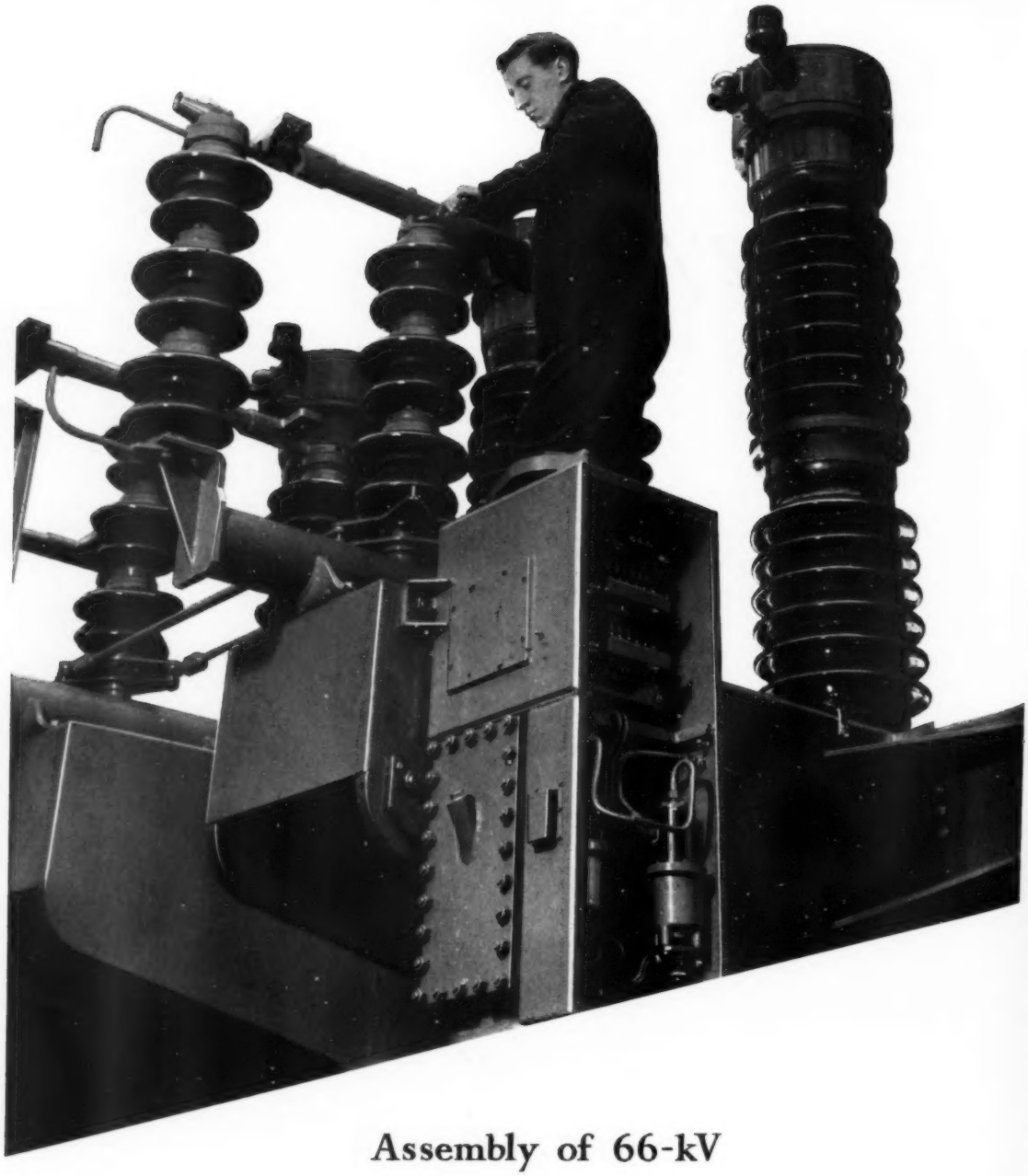
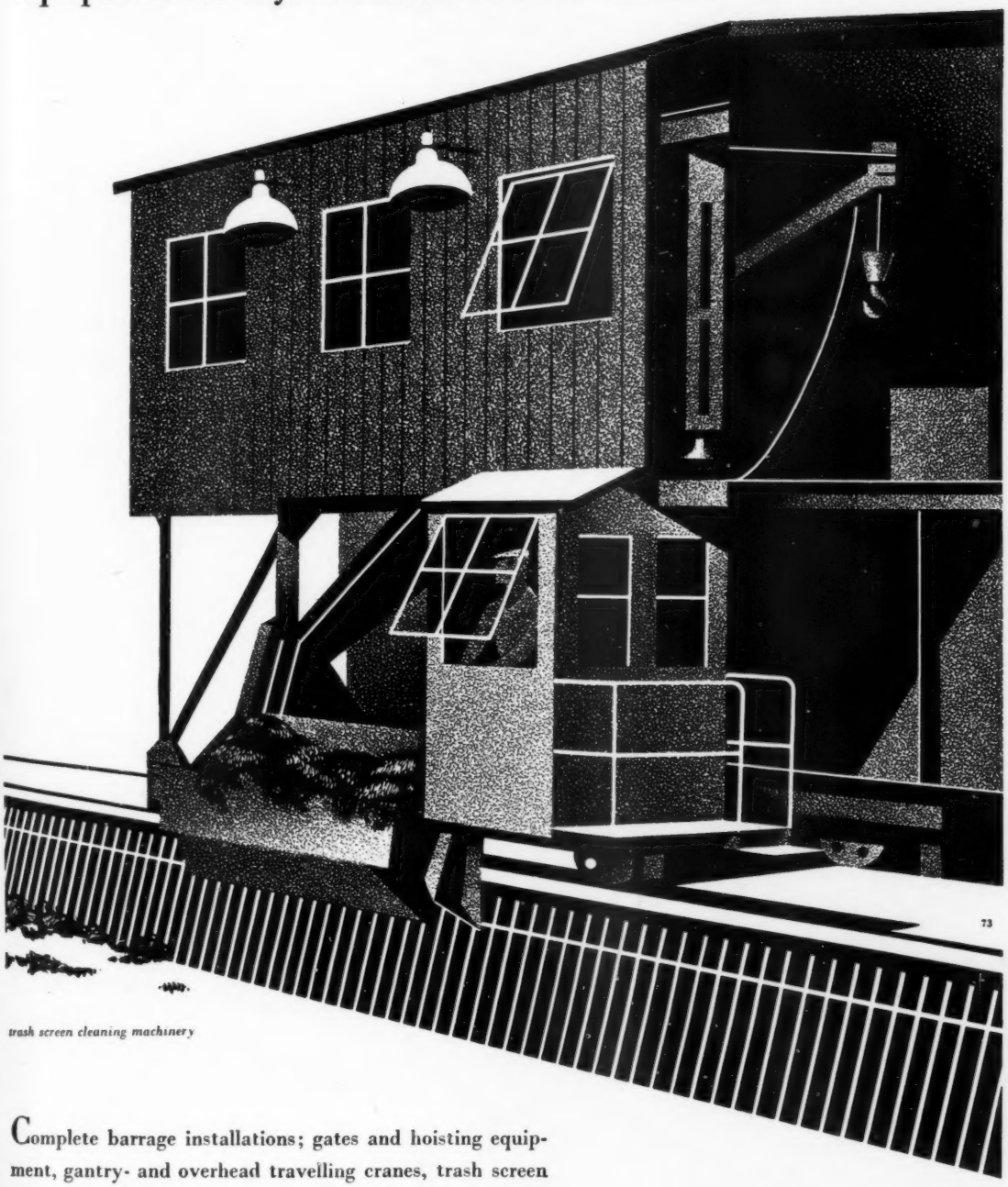


Assembly of 66-kV small-oil-volume circuit-breaker and busbar-isolator

Reyrolle

A. REYROLLE & CO. LTD., HEBBURN-ON-TYNE, CO. DURHAM

Equipment for Hydro-Electric Power Stations



trash screen cleaning machinery

Complete barrage installations; gates and hoisting equipment, gantry- and overhead travelling cranes, trash screen cleaning machinery; sluice gates; control valves for high pressure conduits; automatic safety organs for pipe lines; discharge regulating valves, rotary valves with rotary-piston servomotors, needle valves, butterfly valves, high pressure fittings, piping systems for oil and cooling water plant; funicular and aerial cableways for passenger and goods transport; building machinery for dam-building work

DE ROLL

Louis de Roll, Ironworks Ltd., Works at Gerlafingen, Klus, Choindez, Rondez, Olten, Berne (Switzerland)

SAE: OVER 25 YEARS DESIGNERS, SUPPLIERS AND CONTRACTORS FOR:

Power transmission lines
Railway, tramway and trolley-bus contact lines
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Lattice towers for power lines and substation structures
Steel structures for industrial buildings, warehouses and radio towers
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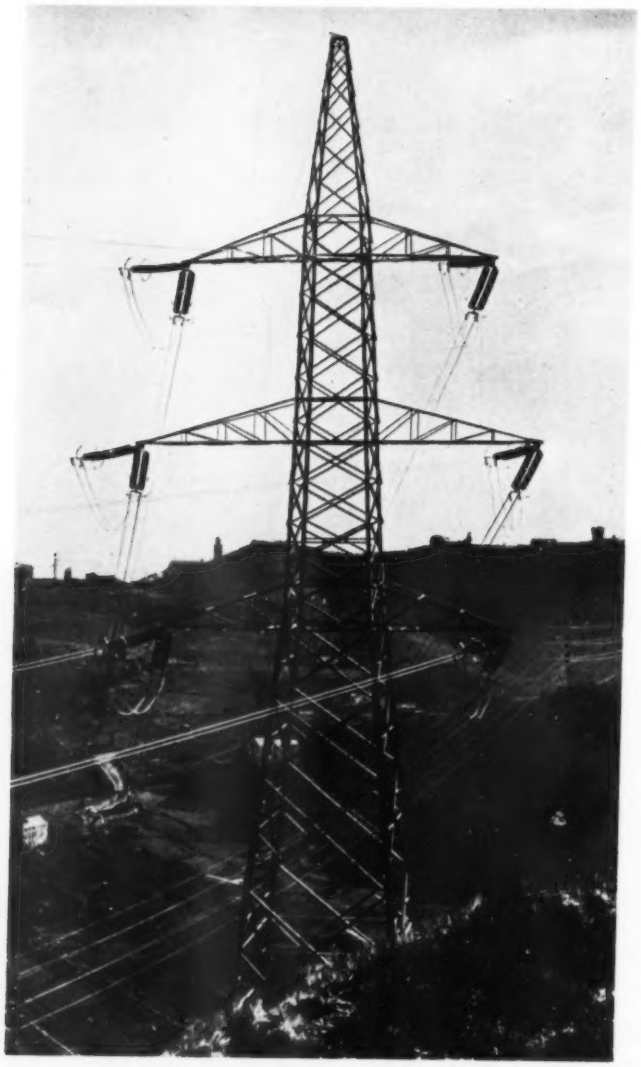
Galvanized fittings for electric lines and substations
Erection equipment



GALVANIZED STEEL ANGLE TOWER

This 230 kV transmission line, built to feed the new Iron and Steel Works at Cornigliano in Italy, is designed to carry six twin 300 sq. mm. (.257 sq. ins. C.E.) S.C.A. conductors across very rough country with ice loadings up to 8 kg/m (5,4 lb/ft).

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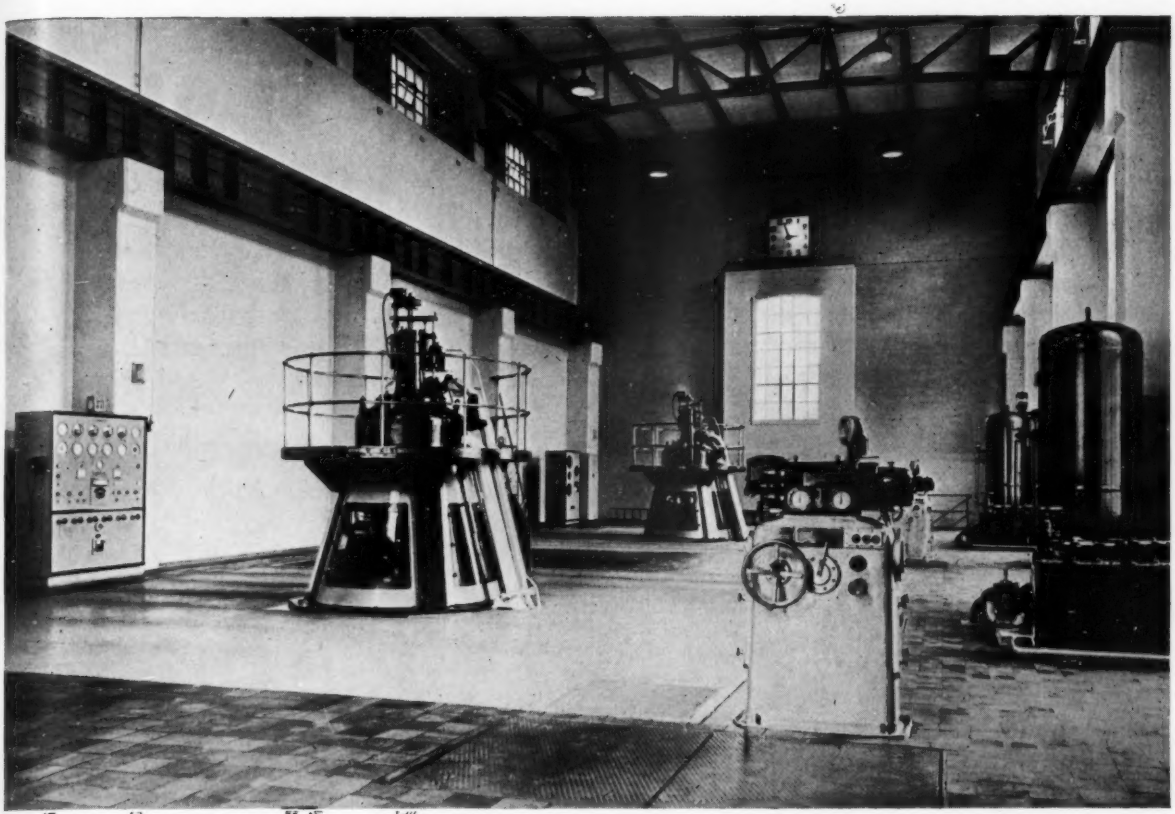

'Kaplans for low heads'

a typical development

Boving Kaplan turbines have been installed in many major hydro-electric plants throughout the world and are operating at high efficiency under widely diverse conditions of head and output. The first plant was installed in 1929 in New Zealand. The best technical knowledge and experience together with thorough workmanship is incorporated in every Boving installation.

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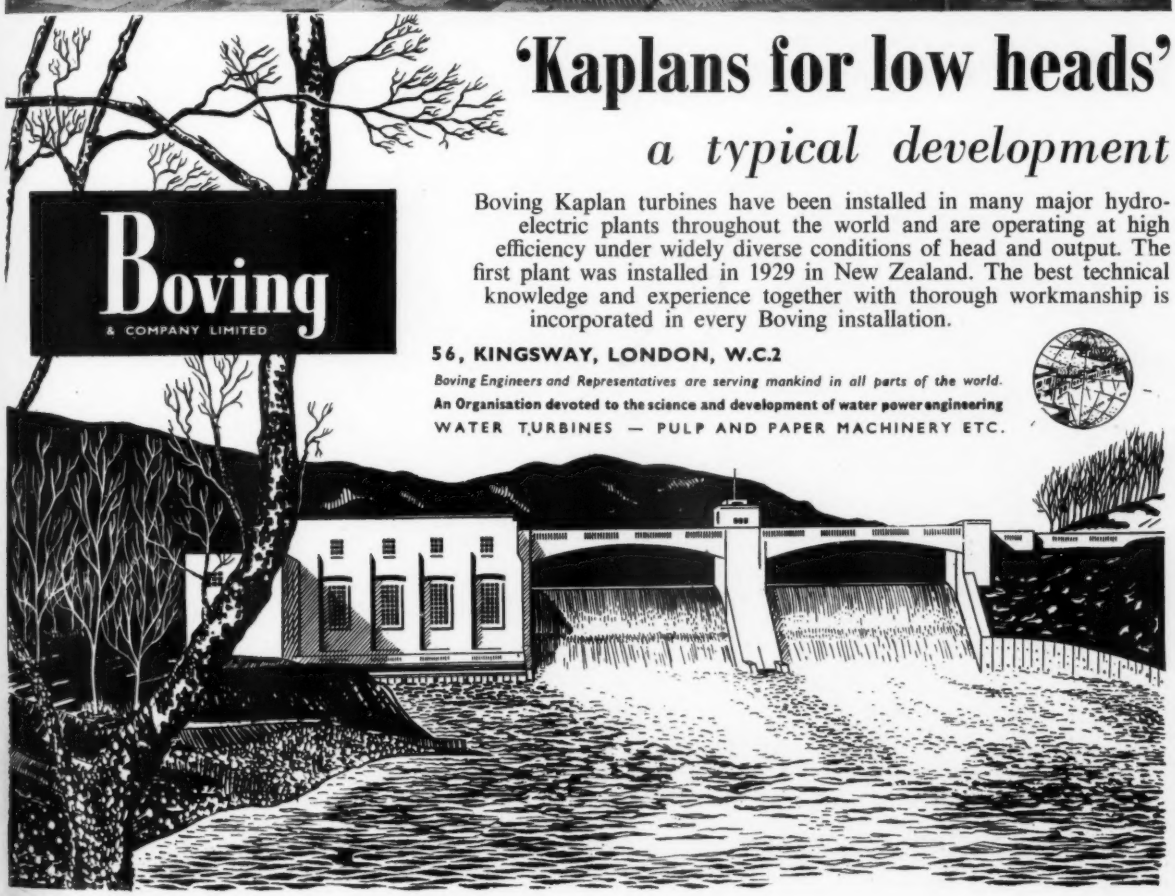
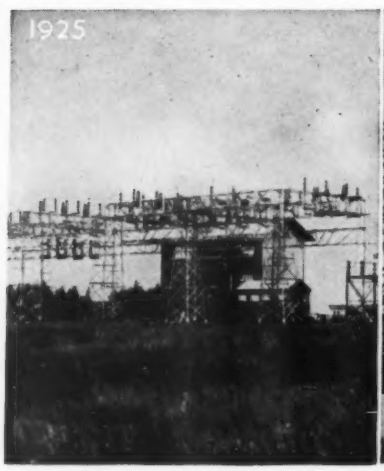


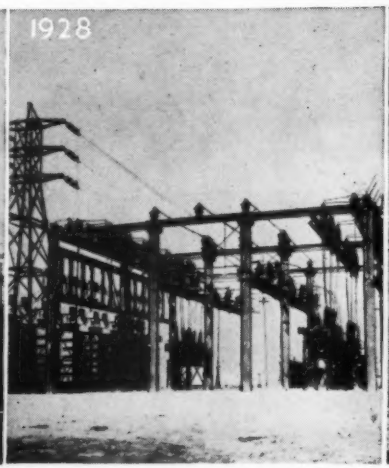
OUTDOOR SWITCHGEAR

Spanning thirty years of progress

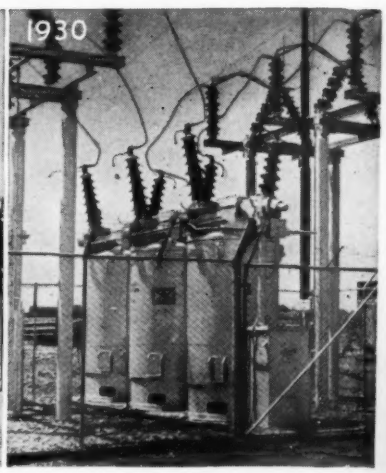
BTH have specialised in high-voltage outdoor switchgear for over 30 years. Many hundreds of breakers have been installed in this period in all kinds of climate, including sub-tropical and tropical. The large number of orders in hand include thirteen "Shuntarc" breakers for 220-kV service in Australia, and seventeen for the 275-kV British Super Grid. This breaker is also available for duty at 330-kV and above.



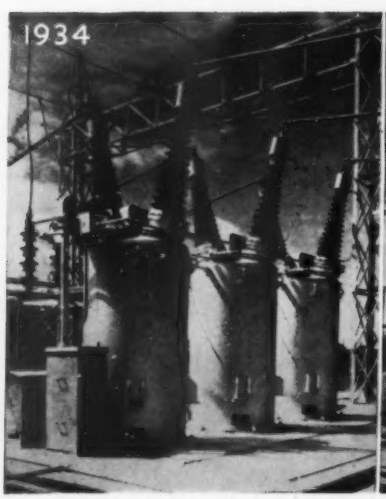
Bunnythorpe, New Zealand



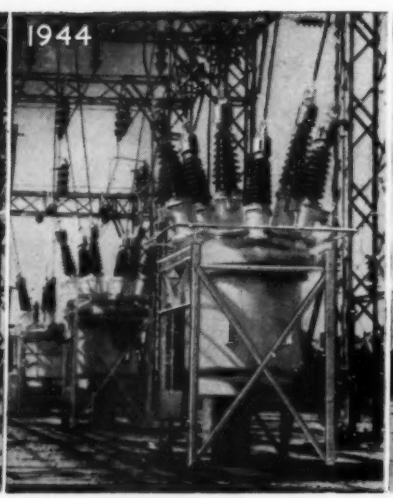
Singu, Burma



Klerksdorp, South Africa



Shalamar, Punjab



Erode, Madras

For Australia & British Super Grid

Whenever switchgear is needed—specify BTH

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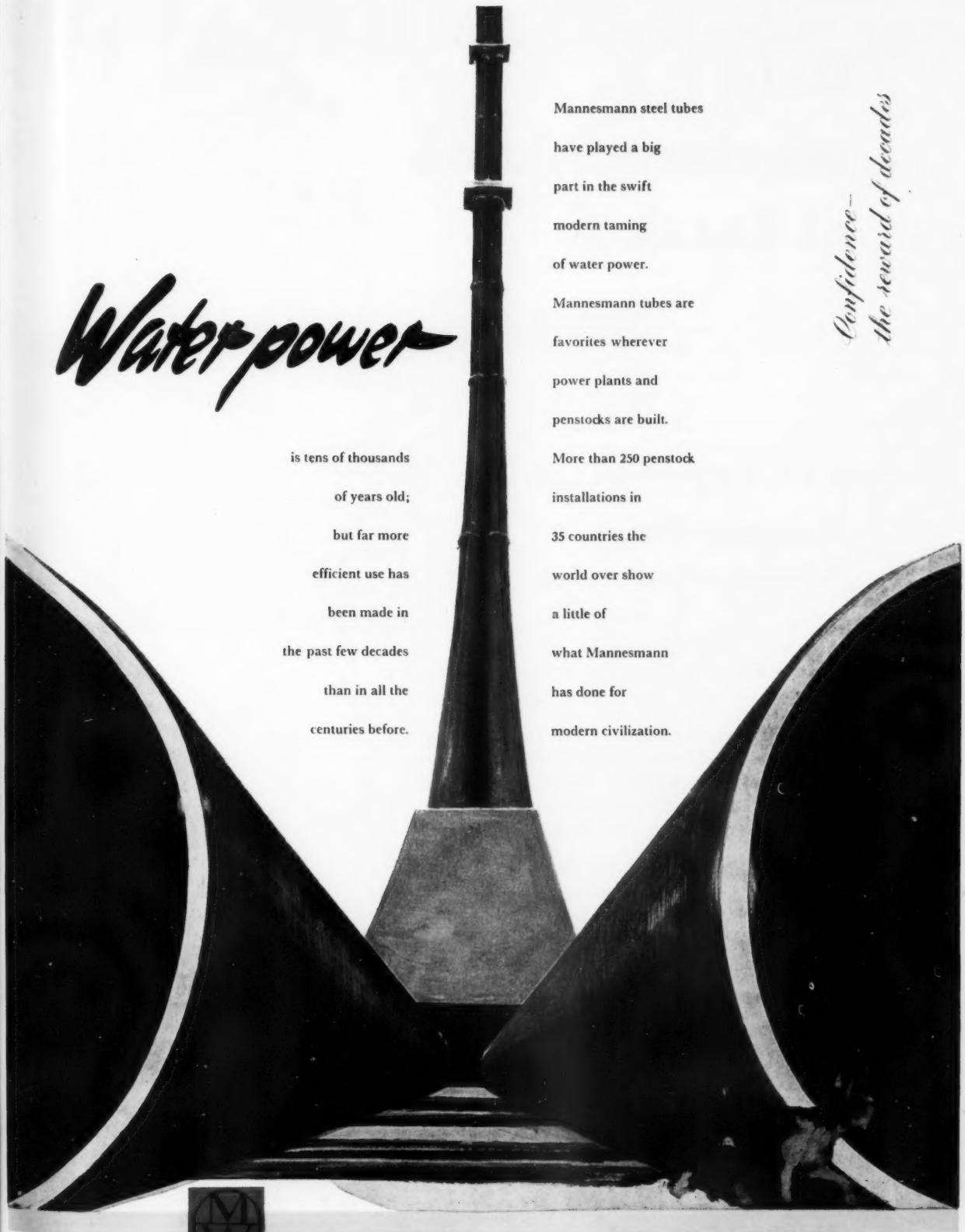
Water power

is tens of thousands of years old; but far more efficient use has been made in the past few decades than in all the centuries before.

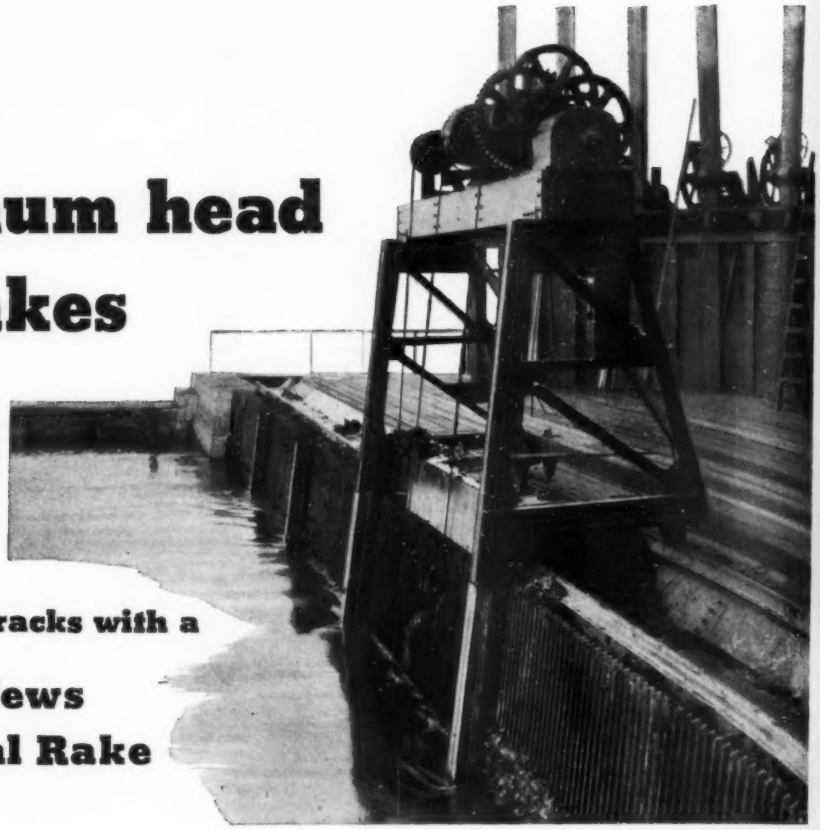
Mannesmann steel tubes have played a big part in the swift modern taming of water power. Mannesmann tubes are favorites wherever power plants and penstocks are built. More than 250 penstock installations in 35 countries the world over show a little of what Mannesmann has done for modern civilization.

Confidence — the reward of decades



MANNESMANN-EXPORT GMBH DÜSSELDORF

Gain maximum head at Intakes



...by cleaning your racks with a

Newport News Mechanical Rake

Keeping racks clean is essential wherever a few inches of head loss can reduce output of the wheels.

One company calculated the capitalized value of each inch of head gained at its plant as $6,000. Measured in terms of the value of additional power output, a Newport News rack rake installed at this plant is paying for itself over and over again the year 'round.

Power-operated to clean trash racks at water intakes of hydroelectric plants, steam plants, pumping stations, canals and similar installations, the Newport News Mechanical Rack Rake reduces a major hand-labor task to one of minor periodic activity.

Under ordinary conditions, one man per shift can, with a Newport News Mechanical Rack Rake, keep the racks clean for a dozen bays.

Write for your copy of "RACK RAKE," an illustrated booklet describing the operation and advantages of the Newport News Mechanical Rack Rake. Use the convenient coupon now.

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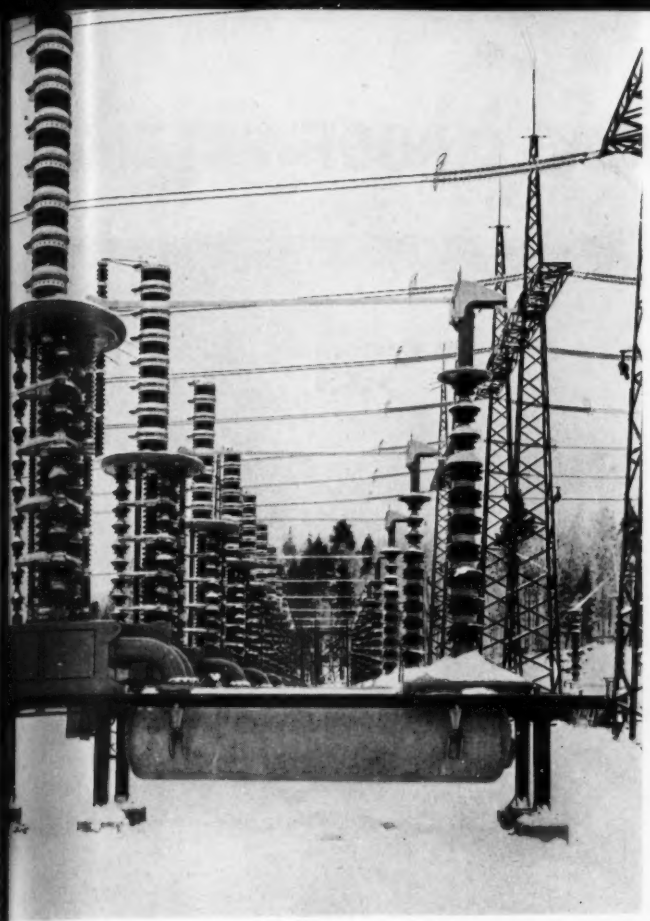
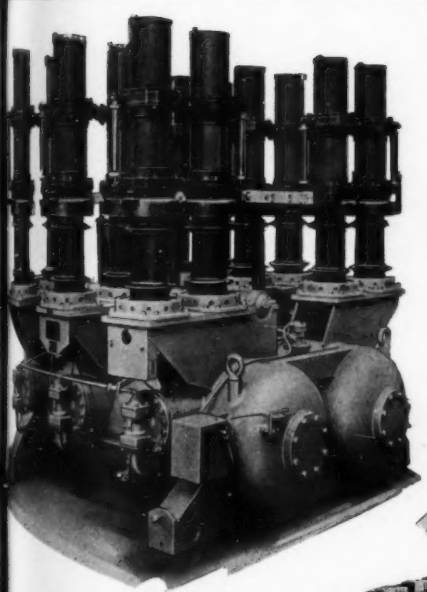
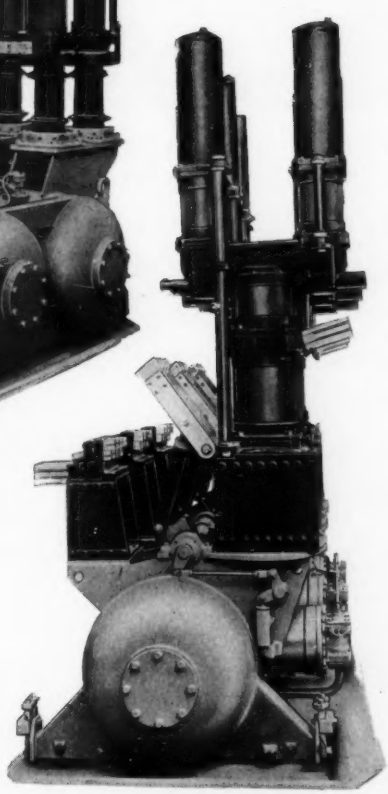
The Swedish
380 kV
Transmission Line



Three of the seven 380 kV air-blast breakers, 1,000 A, 8,000 MVA.



Air-blast breaker for phase shifting transformer, 30 kV, 2,500 A and a breaking capacity of 2,300 MVA.



Air-blast breaker for 20 kV, 5,000 A and a breaking capacity of 2,000 MVA.

The 900 km long transmission line from Harsprånget to Hallsberg was put into service at full voltage on the 6th of April 1952, and since then it has been in continuous operation. The only faults have been caused by lightning strokes on the line and these were cleared by the equipment in the normal way. For new and pioneer equipment this is something of an achievement.

All the high voltage breakers used were supplied by ASEA and most of them were specially developed for the 380 kV system. The ASEA deliveries included the following air-blast breakers:

7 three-pole outdoor breakers, 380 kV, 1,000 A, 8,000 MVA.

5 three-pole outdoor breakers, 220 kV, 1,000 A, 5,000 MVA.

1 three-pole indoor breaker for the phase shifting transformers, 30 kV, 2,500 A, 2,300 MVA.

8 two-pole indoor breakers for transformers, 30 kV, 2,500 A.

8 three-pole indoor breakers for generators and transformers, 20 kV, 5,000 A, 2,000 MVA.

16 two-pole indoor breakers for transformers, 16 kV, 3,000 A.

The breakers meet the requirements of SEN 31 and the acceptance tests at Harsprånget showed that the 380 kV breakers meet the additional requirements, specially imposed for this system, with an ample margin.

The pioneer work which ASEA has laid down in the development of these breakers and the experience won in all kinds of breaker problems has been of tremendous advantage to our entire range of production.

Consult us regarding high voltage breakers.

Make use of our experience.

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Dry and Dustfree ROOF-BOLTING

The whole technique and process of roof bolting can be immensely simplified and accelerated by using the Holman DRYDUCTOR — the only dry rock drill in the world which is designed for completely *dust-free* drilling. Whatever the drilling angle, the DRYDUCTOR produces *no chippings, no dust — no sludge.* All dust is extracted as it is made, passed through the hollow drill steel and out through the rear of the machine. No water is used or needed. The DRYDUCTOR is a completely practical machine, calling for no special techniques or conditions.

IMPORTANT. The DRYDUCTOR cannot release dust while it is drilling, and it cannot operate unless the dust is being extracted.

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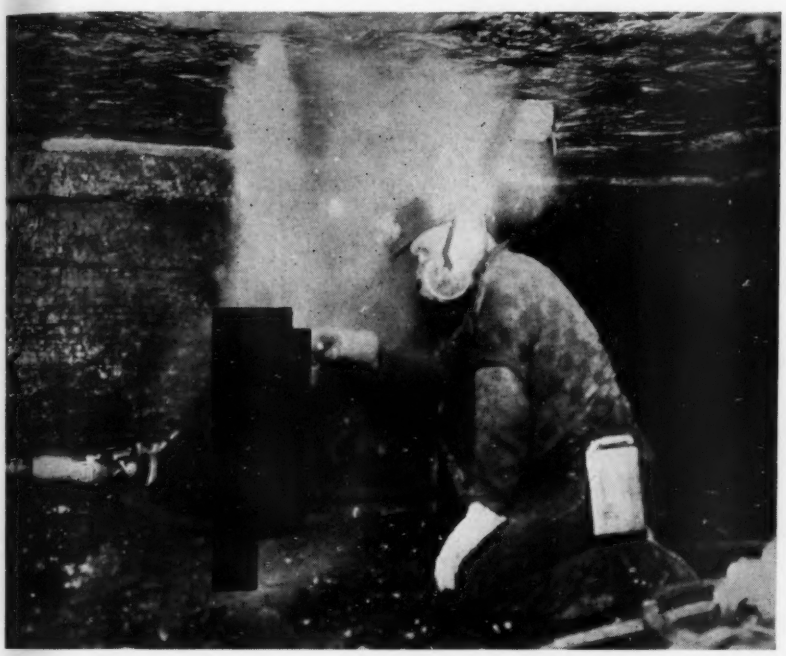
-begins with the Holman DRYDUCTOR

(Reg'd Trade Mark)

◀ *(Left) Drilling a hole in a roof using the DRYDUCTOR. Note absence of dust clouds. (Only machine exhaust.)*



DRYDUCTOR mounted on Holman Telescopic Stoperleg.

▲ *(Above) The old way. Clouds of dust set up by a dry rock drill used for roof bolting. The machine has been obliterated.*

Photos by courtesy of Dominion Steel and Coal Corporation of Sydney, Nova Scotia.

- **Drilling speeds are maintained when the Dryductor is used — because a new face is presented for each blow.**
- **Equally effective for all rock-drilling operations — at any angle.**
- **Designed, developed and produced exclusively by Holman Brothers.**
- **THE DRYDUCTOR can easily be used on any type of Mounting, including the Airleg and the Double Telescopic Stoperleg.**

Holman

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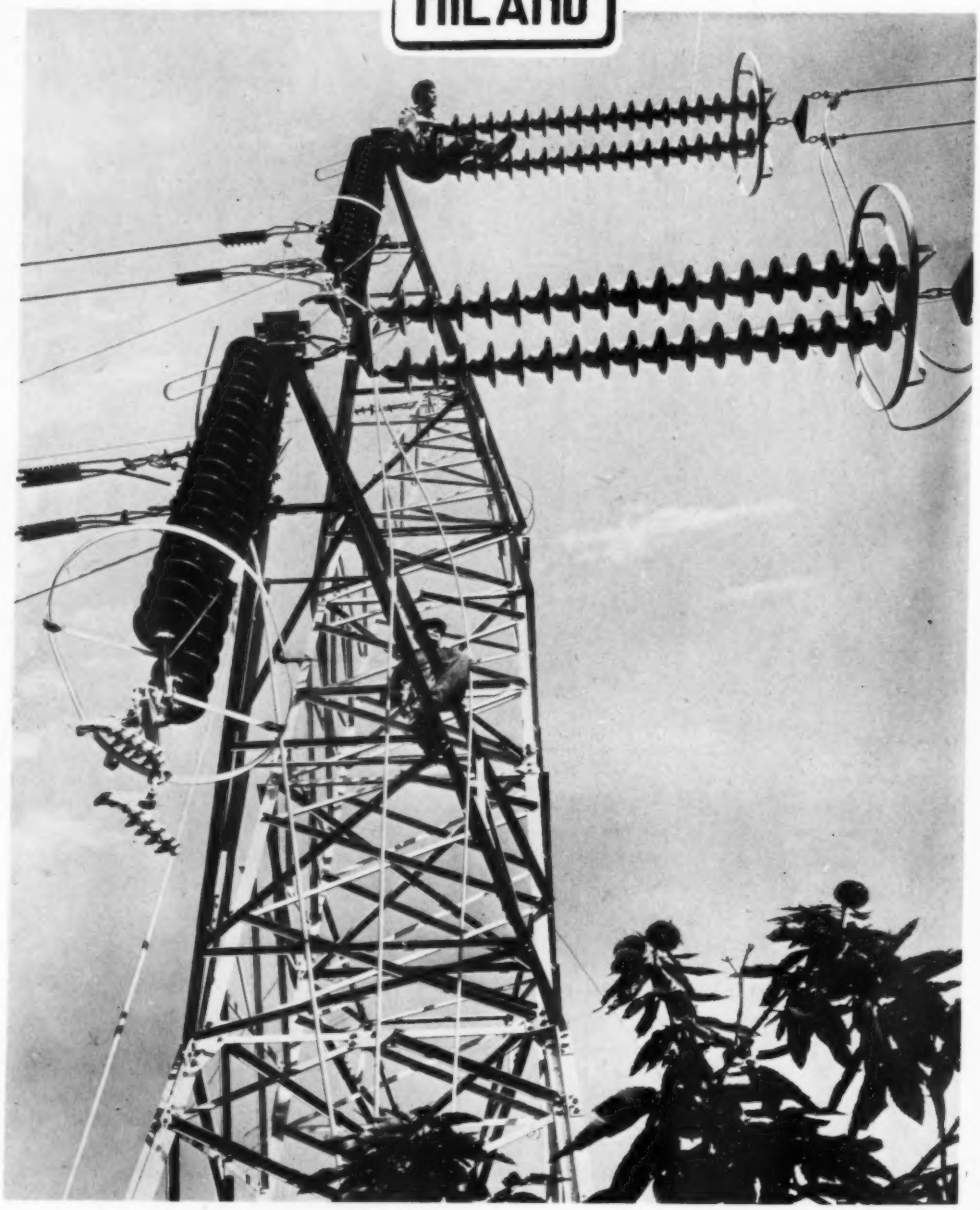
HIGH VOLTAGE SALVI IFI MILANO LINE FITTINGS



3-230 kV Villa Valle-Cornegliano 4 Twin S.C.A. Conductor Transmission Line (Societa TERNI-Rome)

For 30 years Messrs. A. Salvi and Company, Milano, Italy, have specialised in the design and manufacture of complete equipment for Overhead Transmission Lines, including Compression Dead End Assemblies and Joints. Suspension and Strain Clamps. Arcing Horns. Guard Rings. Shackles. Armour Rods. Galvanized Bolts and Nuts, etc.

The Works of the Salvi Company are engaged exclusively in the production of high grade fittings for High Voltage Transmission Systems, up to and including pressures of 220/380 KV, and for all sizes of Copper, A.C.S.R. and Aluminium Alloy Conductors.

We shall be glad to receive enquiries and to provide a data sheet indicating the details we require to enable us to quote for your requirements.

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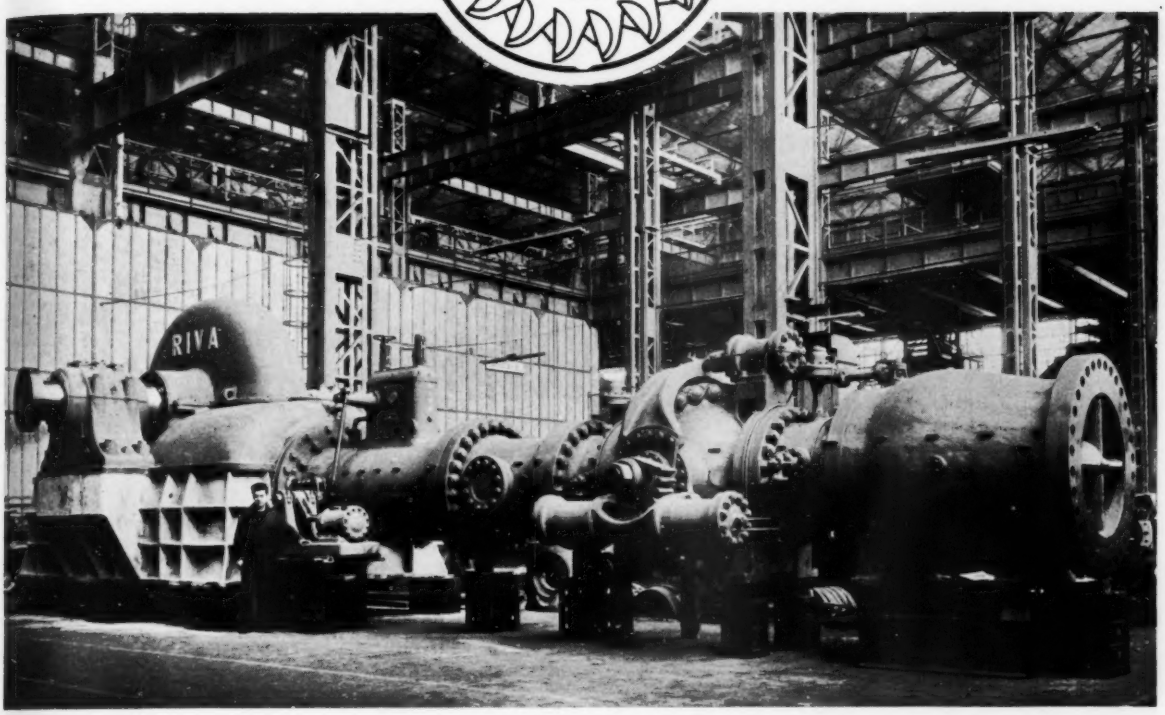
PELTON RIVA TURBINES



62,000 H.P. Single Runner Single Jet Riva Impulse Turbine

The Turbine Unit illustrated is now in course of being installed at the Avise Power Station, Italy, and is one of two such Units designed and constructed by Riva for the Societa Idroelettrica Piemonte, Turin.

The Turbines are fitted with the Riva patent straight flow Nozzle, Riva patent spherical valve, and an axial emergency valve.

It is believed these are the highest powered Single Runner, Single Jet Turbines that have yet been built.

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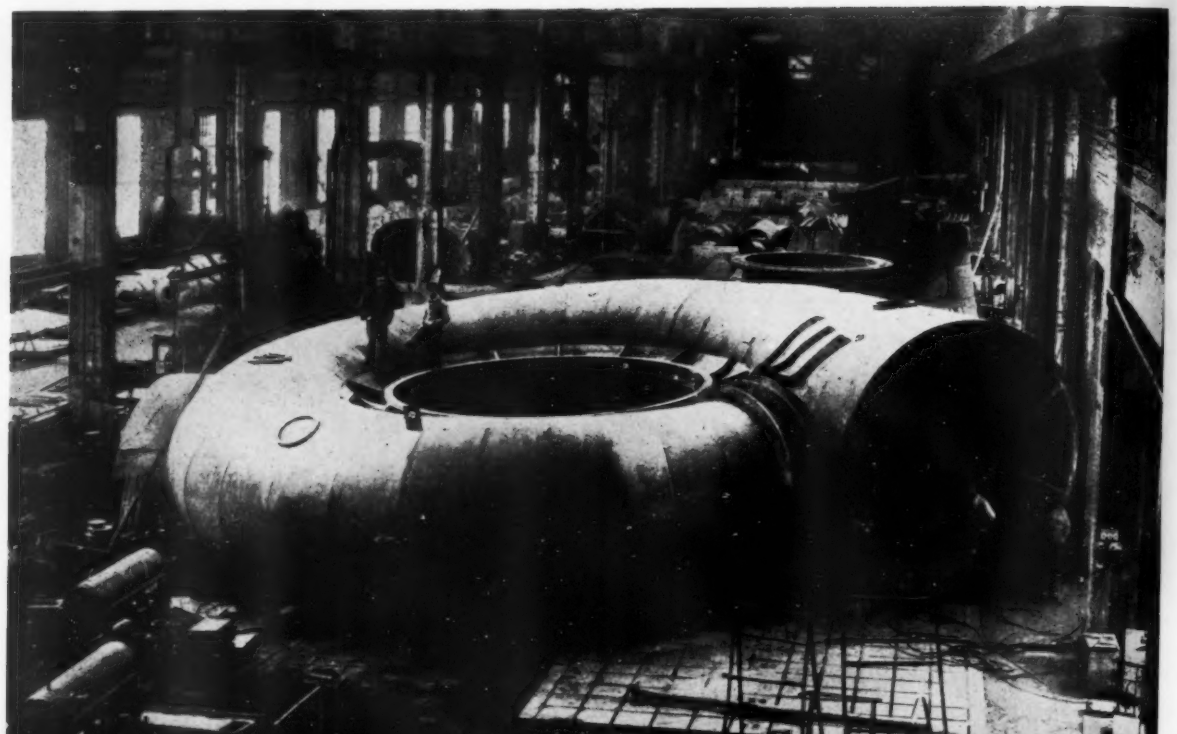
HYDRAULIC TURBINES

KAPLAN ★ FRANCIS ★ PELTON ★ GOVERNORS ★ VALVES



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50-ft. . . . 250-ft. . . . 500-ft. . . . the CP-55 Diamond Drill is built to do the job quickly and efficiently. Whether it be coring, blast hole drilling or grout hole drilling, this latest CP machine has all the features demanded by civil and mining engineers today . . . ample power, high capacity, self aligning rod puller, high torque air motor, spur gearing and solid construction. The CP-55 Diamond Drill certainly justifies its inclusion in the well known range of CP rock drilling equipment.

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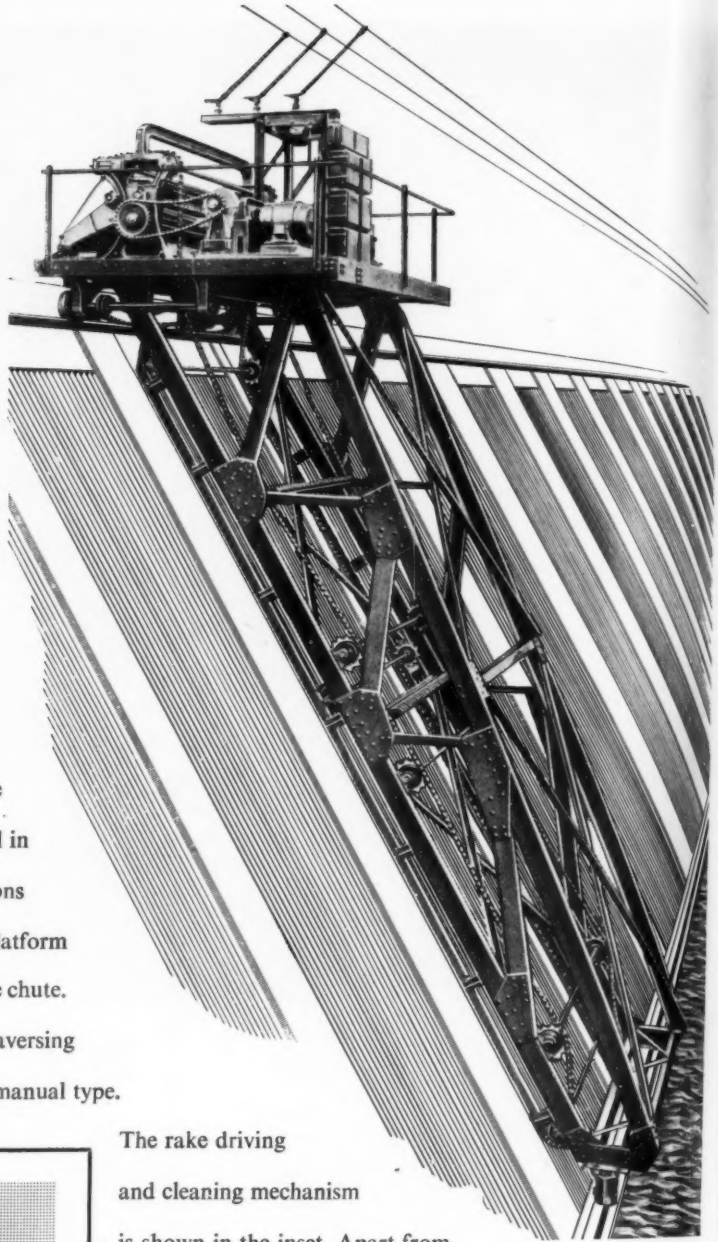
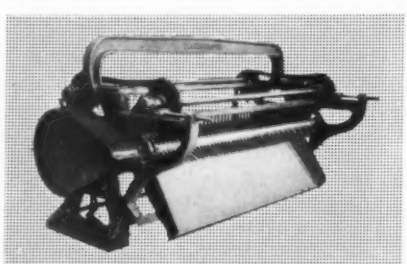
Screens and raking machines



We illustrate here one of our travelling raking machines for bar screens or trash racks, useful where considerable widths are involved. The machine is arranged to travel in a series of stages, raking successive portions of the screen, and carrying the debris up to platform level, where it is cleaned off into a discharge chute. The raking gear is power driven, and the traversing gear can be of either power driven or manual type.



We also supply the actual bar screens, in a choice of constructions, and to suit any form of layout.

The rake driving and cleaning mechanism is shown in the inset. Apart from its use on the above, it can be supplied for installation as a separate, stationary unit, built to suit short widths of screen (up to 9′ 6″), and arranged for either manual or power operation. All machines are of top quality design and manufacture.

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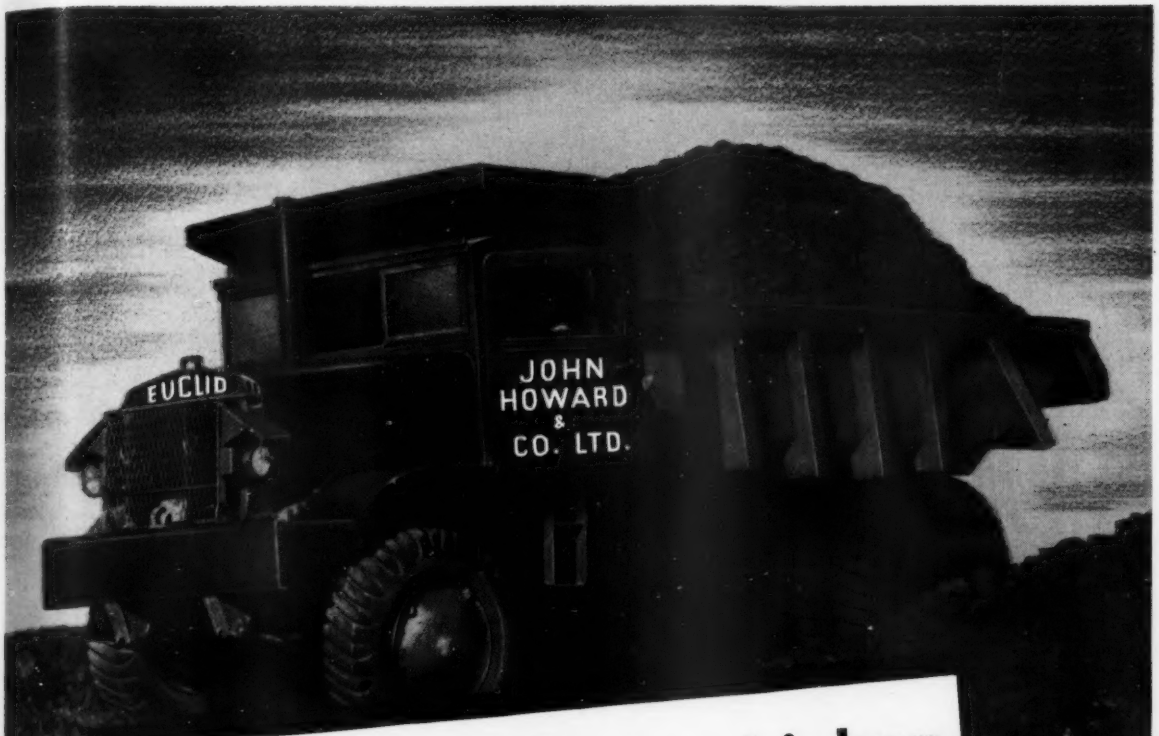

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Like so many famous civil engineering contractors, John Howard & Co. Ltd. use EUCLID Rear-Dump Wagons for large scale earthmoving on their many important contracts in the U.K. and overseas, including Kuwait State Development at present being undertaken by their associate Company, Construction & Contracting Co. (Kuwait) Ltd.

All over the world, on all types of important projects involving large scale earthmoving, EUCLIDS are carrying more loads in less time . . . cutting overheads, increasing operators' profits.

EUCLID Rear-Dump and Bottom-Dump Wagons and EUCLID Tractors and Scrapers are available for Sterling. Place your order now—all orders executed in strict rotation.

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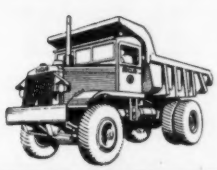
BLACKWOOD HODGE



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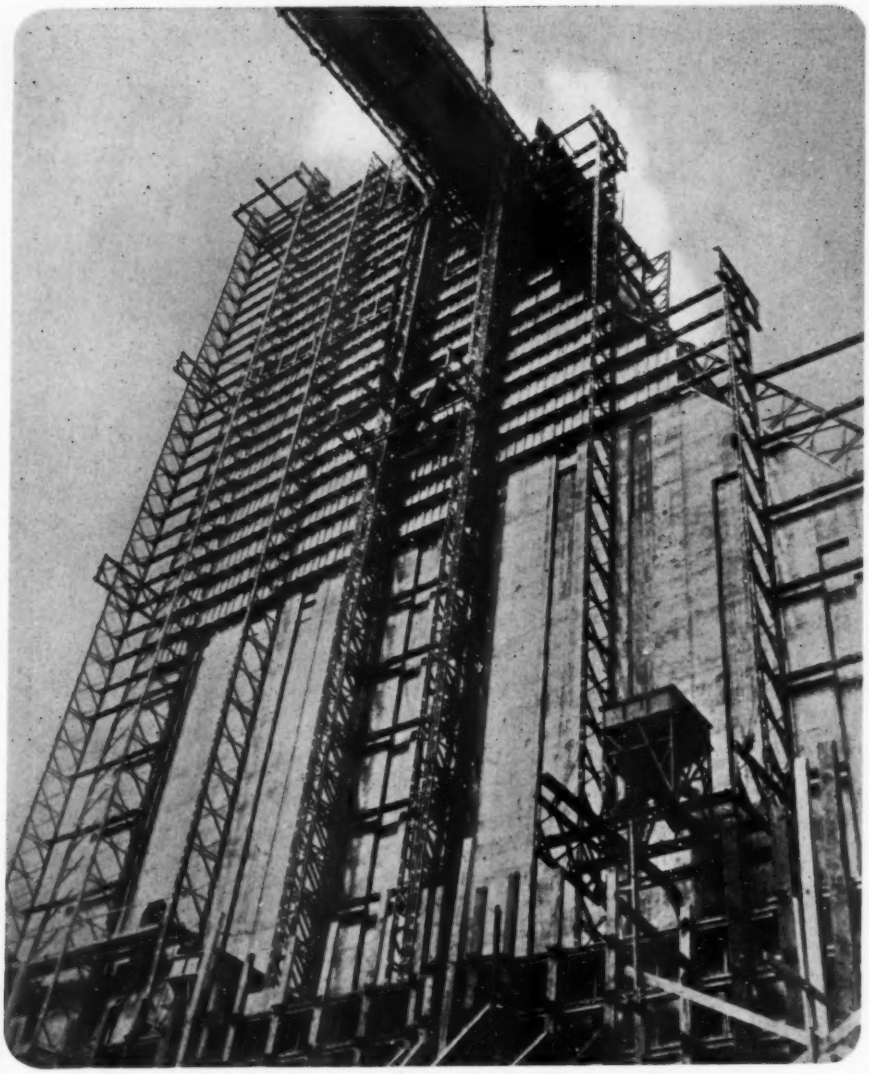

Photograph by courtesy of the Ontario Hydro Electric Commission

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in this age of power

Engineers throughout the world, engaged on major projects to harness natural resources, combine the structural and mechanical aids of Bailey Bridging with their technical and productive skill. To-day's tremendous speed of construction demands Bailey Bridging equipment which fulfils all requirements, regardless of magnitude. Our organization is privileged to place at your disposal a world-wide technical and Bailey Bridging supply service, unique in Civil Engineering.

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Night - *like the Light of Day*

THE SUN drops behind distant hills . . . Darkness enwraps our material existence . . .

But night has little of its pristine terror and tragedy . . .

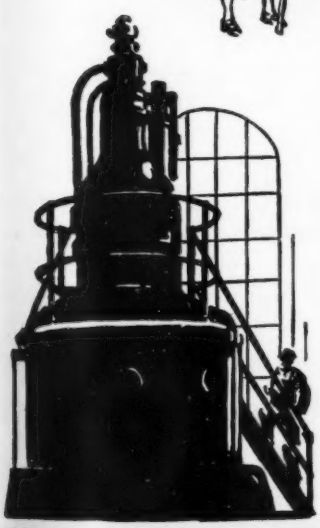
For witness a wondrous transformation . . .

Electricity dispels the darkness—and the *light of day returns!*

Streets become safer . . . Emergencies in the home and hospital are met . . . Industry functions with nightshifts . . . and storekeepers pursue their trades! . . .

Because of ELECTRICITY generated, often times, hundreds of miles away, mighty hydraulic turbines tirelessly transform water's energy into useful mechanical energy for the benefit of man!

For more than 77 years, we have pioneered and led in this utilization of water. As a result, we have a wealth of experience and engineering skill *which you can use at a profit by placing your power problem in our hands!*



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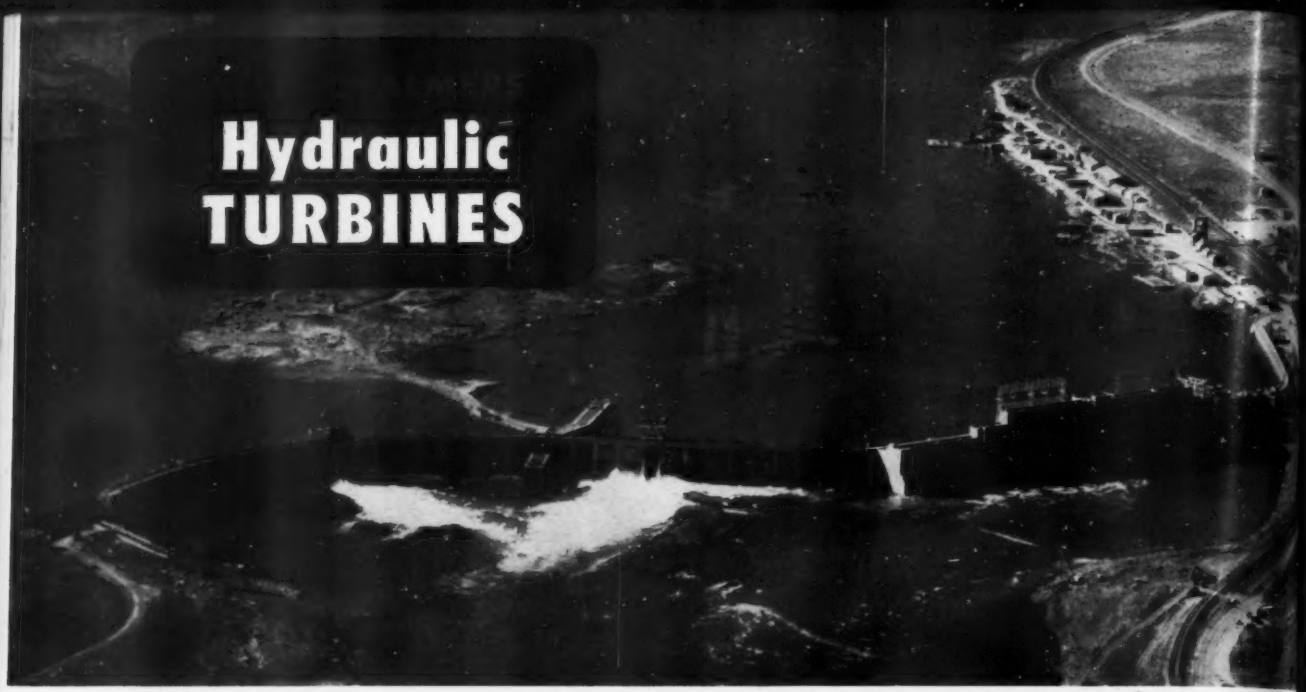
Manufacturing Licensees for the British Commonwealth.

POWER by SMITH



Closing a Power Gap

Six New 34,000-Hp Hydro-Electric Units Match Booming Industrial Power Demand

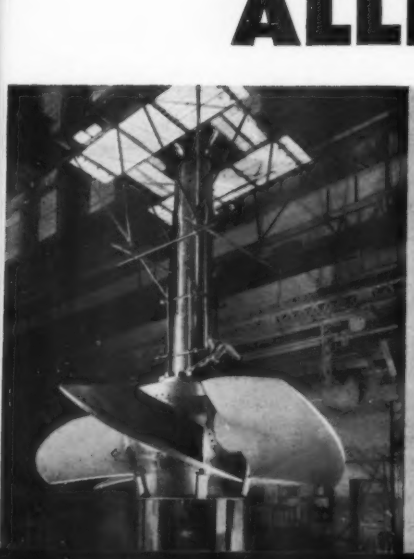
RECENT industrial growth in the United States Pacific Northwest region has been swift. So swift that electric power demand began to outrun the area's installed capacity. Prompt delivery of six 34,000-hp Allis-Chalmers turbines and generators for the Rock Island Plant on the Columbia River helped to close the power gap.

The Rock Island Plant originally went into operation in 1932 with four Allis-Chalmers propeller-type turbines rated 21,000 hp at 32 ft normal head. Subsequent raising of the Rock Island Dam by Public Utility District No. 1 of Chelan County provided a 45 ft normal head for the six 34,000-hp, 100-rpm, Kaplan-type adjustable-propeller turbines installed in 1952-1953.

With half a century of turbine building experience, A-C can furnish Francis, propeller or impulse-type turbines together with governors, regulators, valves, and synchronous or induction generators to suit any application. For your convenience, A-C has 95 sales offices and 65 distributors located in 53 countries. For more information ask for Bulletins 01B7301 and 05B7549. Allis-Chalmers, Milwaukee 1, Wisconsin, U.S.A.

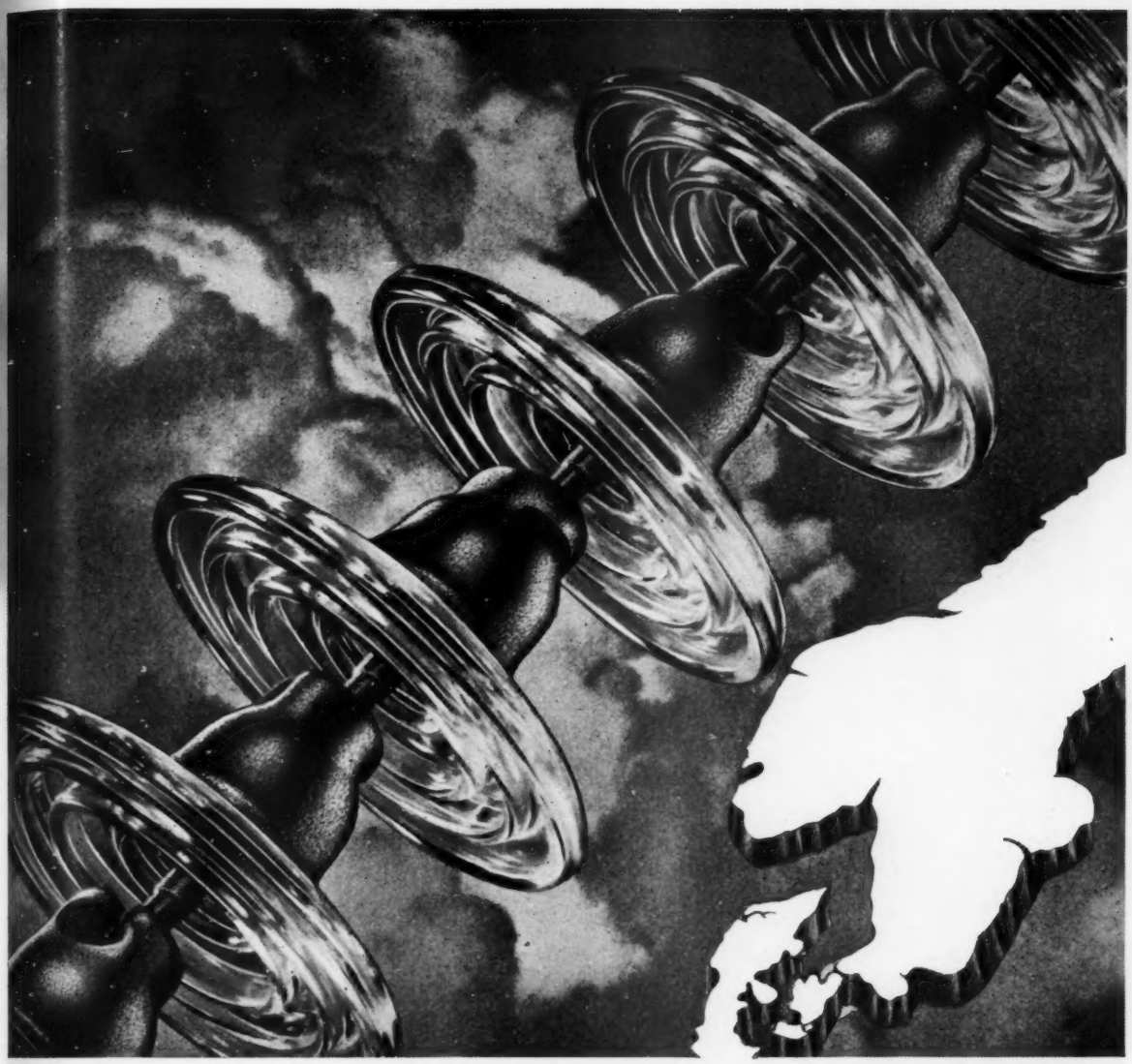
A-4180

ALLIS-CHALMERS



Aerial view above shows enlarged Rock Island Plant on Columbia River. Supplementing the four original 21,000-hp turbines, the six new 34-000-hp units drive 25,000-kva, 0.9-pf, 13,800-volt Allis-Chalmers generators, adding a capacity of 150,000 kva to serve growing industrial power requirements.

Views at left and right show the runner and internal parts for 34,000-hp units during shop assembly in the Allis-Chalmers plant.



Over **half a million** in Scandinavia

As the world's power-lines lengthen, the demand for "ARMOURLIGHT" Toughened Glass Insulators gets steadily larger. The United Kingdom and Eire already have 2 million in service. Australasia and Africa, in spite of their thinly distributed electric transmission systems use about a million each. Scandinavia has bought more than 500,000. They have an impulse electric strength four or five times greater than porcelain. The most stringent laboratory tests have shown that they are proof against puncture by lightning surges, and their resistance to power arcs is twice as great as porcelain. Finally, if an "ARMOURLIGHT" Insulator does break, it shatters completely. The fault can be seen at first glance, from the ground, or from a low-flying aircraft. *For technical advice and literature, write to Pilkington Brothers Limited, Insulator Sales Department, Ravenhead Works, St. Helens, Lancs.*

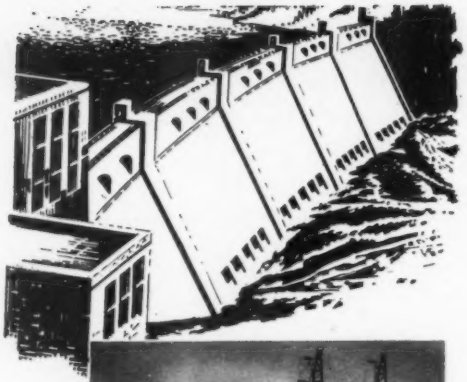
"ARMOURLIGHT"

High Voltage Toughened Glass Insulators

PILKINGTON BROTHERS LIMITED

St. Helens, Lancs., or Selwyn House, Cleveland Row, St. James's, London, S.W.1. Tel.: St. Helens 4001, Whitehall 5672-6

"ARMOURLIGHT" is the registered trade mark of Pilkington Brothers Ltd. HVI.2



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Specially designed for the handling of materials on large-scale construction projects, HENDERSON Aerial Cableways are used in all parts of the world . . . they are found to move bigger loads faster and at lower cost. Low cost materials handling is the key to successful civil engineering undertakings—and wherever there is a dam or barrage, a bridge or viaduct to be built, a Henderson Cableway more often than not will be found to be the most practical means of construction.

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CABLEWAYS ARE ESSENTIAL ON ALL LARGE-SCALE CONSTRUCTION PROJECTS

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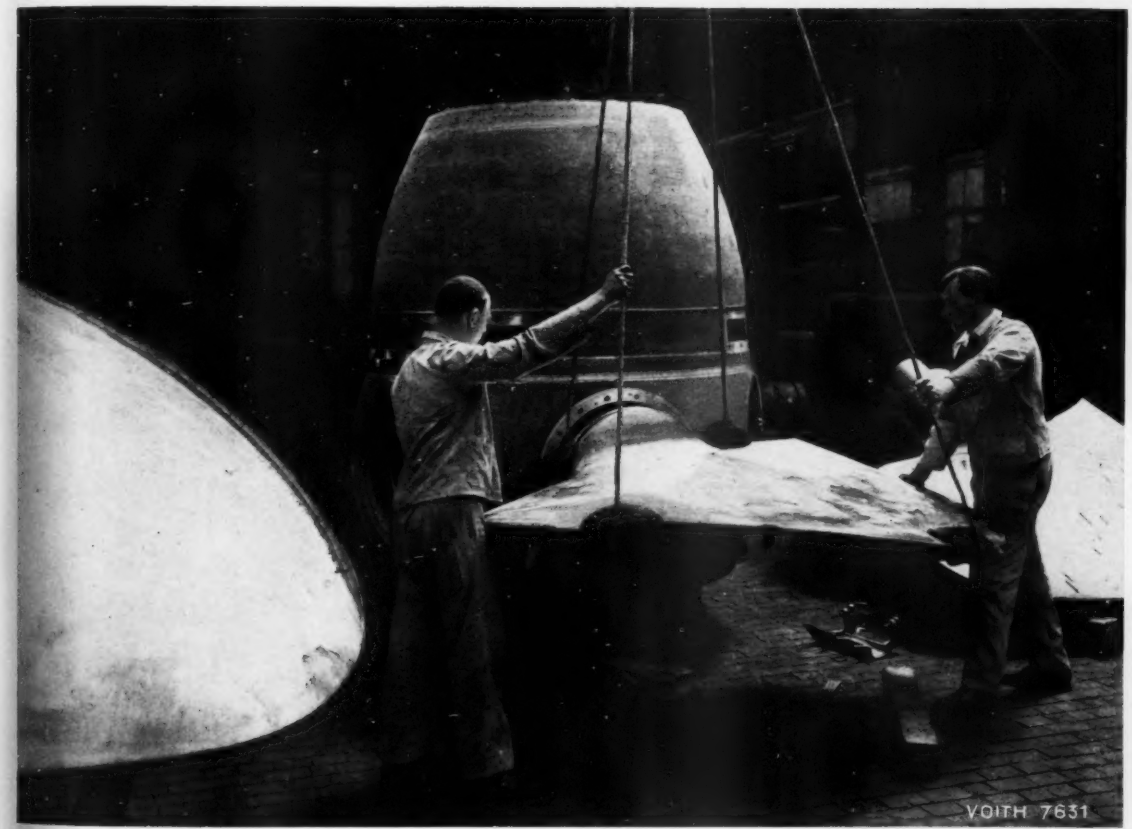
LEADERS IN CABLEWAY DESIGN & CONSTRUCTION

Voith

Some representative figures on water turbines

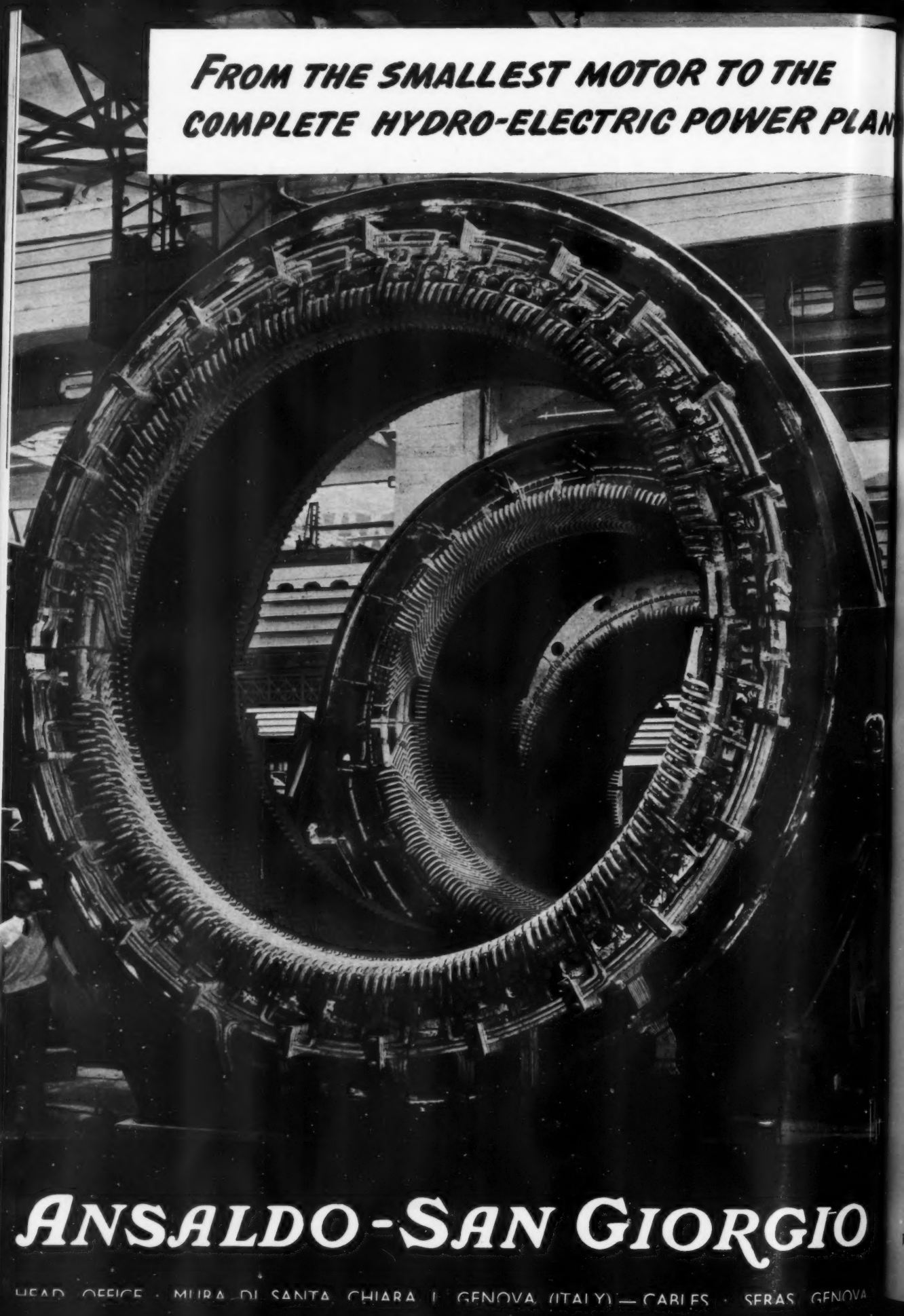
Year	Number of Turbines	Total output in H.P.
1870	1	100
1889	100	10,000
1901	1,000	135,000
1912	5,000	2,000,000
1927	10,000	6,000,000
1950	15,000	14,745,000
1952	15,300	16,000,000

V7821



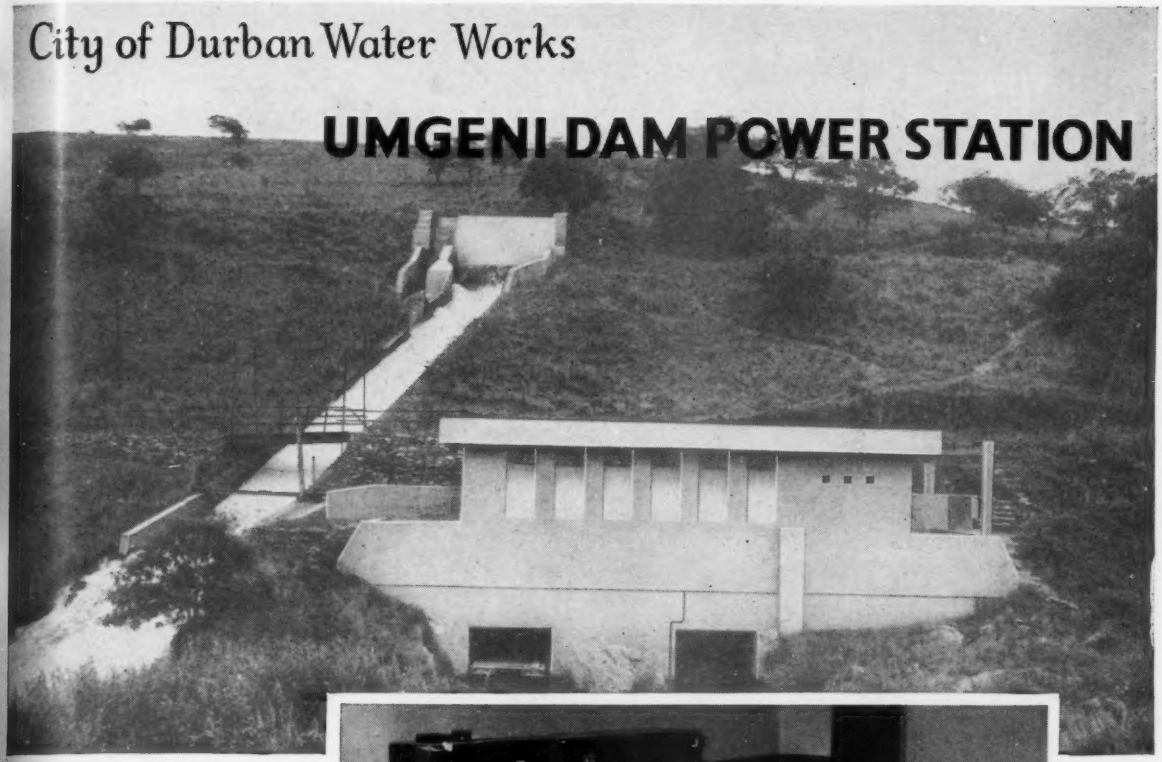
Shop Assembly of a Kaplan Turbine Runner 14′ 9″ Dia. for an Output of 34,100 H.P. under a Head of 77′ 6″, Power Station Hirakud II (India).

J.M. Voith G.m.b.H., Engineering Works, Heidenheim (Brenz)
Telegrams: Voithwerk Heidenheimbrenz Germany (Wurttemberg)

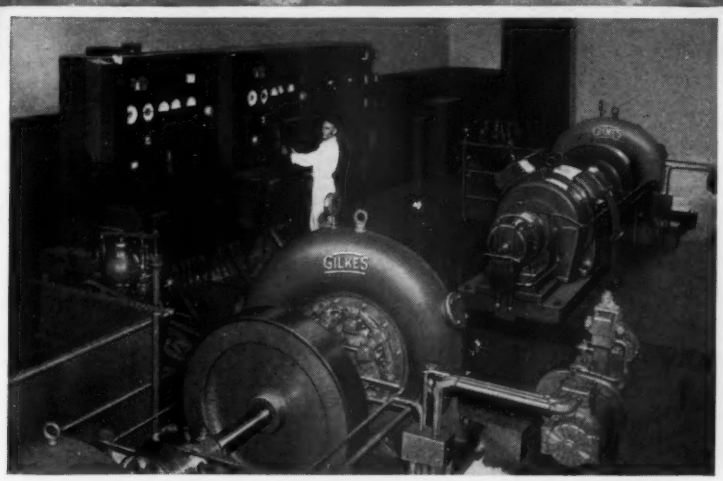

FROM THE SMALLEST MOTOR TO THE
COMPLETE HYDRO-ELECTRIC POWER PLAN
ANSALDO-SAN GIORGIO
HEAD OFFICE · MURA DI SANTA CHIARA 1 GENOVA (ITALY) — CABLES · SERAS GENOVA

City of Durban Water Works

UMGENI DAM POWER STATION



Power station and intake works



Interior of power station showing the two 200 B.H.P. GILKES Francis Turbines

Water supply schemes frequently present opportunities for the installation of small hydro-electric units operating on compensation water from reservoirs or acting as pressure reducers at filter stations. The City of Durban Waterworks installation at Umgeni is a typical example and consists of two 200 B.H.P. *GILKES* Francis Turbines operating on a head of 80 feet. These units were originally used to supply power for constructional work on the dam and now provide electricity for the operation of sluice gates and other equipment at the dam and for the houses of the staff.

GILBERT GILKES & GORDON LTD

KENDAL 'Phone: Kendal 28 ENGLAND

WATER TURBINE AND PUMP MANUFACTURERS

London Office. CRAVEN HOUSE, KINGSWAY, LONDON W.C.2 'Phone: Holborn 3231/2

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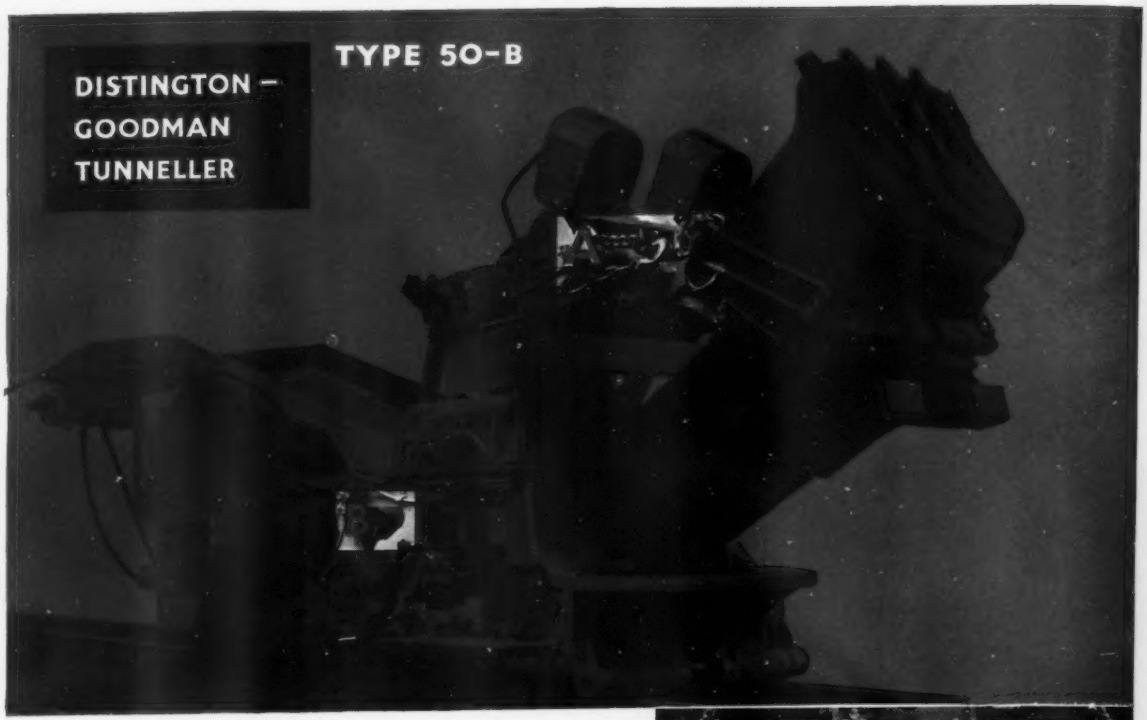
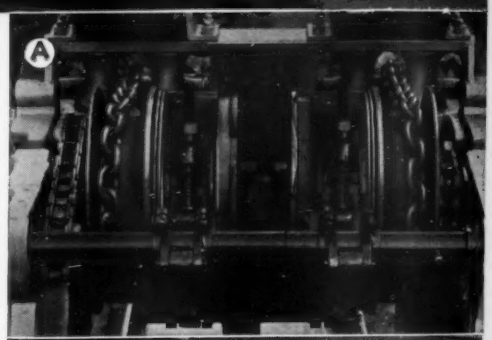


This machine driven by a 50 h.p. flameproof motor, has all its movements (forward and reverse tramming, and hoisting and swinging the boom and shovel) controlled by two hand levers and two foot pedals. Each pedal and lever operates an easily adjusted brake band on a planetary gear drum. There is adequate mechanical and electrical protection against overload.

Power transmission to the planetary gears is by roller chain. A clutch is fitted to disengage the belt conveyor.

The machine is very heavily constructed and, with its simple safe control, is comparatively insensitive to hard usage. The Distington-Goodman range of tunnellers also includes 75 h.p. and 100 h.p. machines; please write for more details.

50 h.p. motor (AC or DC). Dipper capacity—13 cu. ft. 6 loading cycles per min. Loading capacity—81 cu. ft. per min. Tramming speed—176 f.p.m. forward, 120 f.p.m. reverse



BOOM LENGTH	CLEAN-UP AT TRACK LEVEL	OPERATING HEIGHT
5′	13′	8′ 8″
6′	14′ 6″	9′ 8″

DISTINGTON

DISTINGTON ENGINEERING COMPANY LIMITED · WORKINGTON · CUMBERLAND · ENGLAND

GT.5

S.P.P. Post Insulators were specified for the Tarraleah Sub-Station, Tasmania

The Sub-station at Tarraleah, Tasmania, is one of the many 110 kV. and 88 kV. sub-stations on the Hydro-Electric Commission's system equipped throughout with S.P.P. Cylindrical Post Insulators.

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From every point of view

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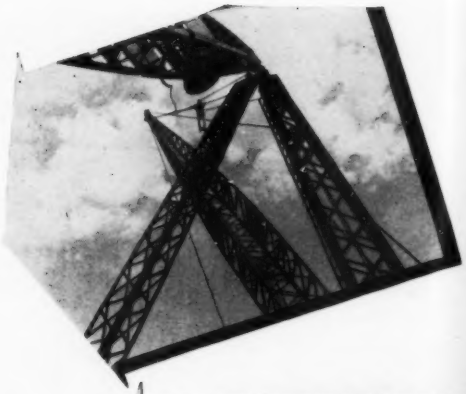

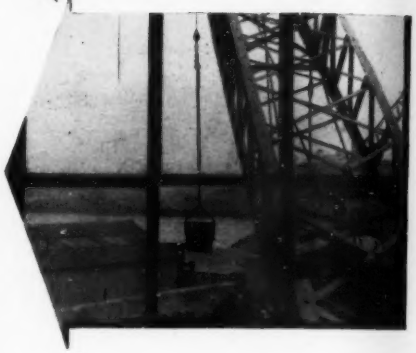

are second to none.....

Full vision of load, fool-proof jib interlock, machine cut gears, ease of operation and maintenance, and robust construction to the most modern standards of design contribute to the outstanding service provided by Butters Derricks. These cranes are made in all sizes and powers, and we shall be glad to submit details of standard models and to quote against requirements.

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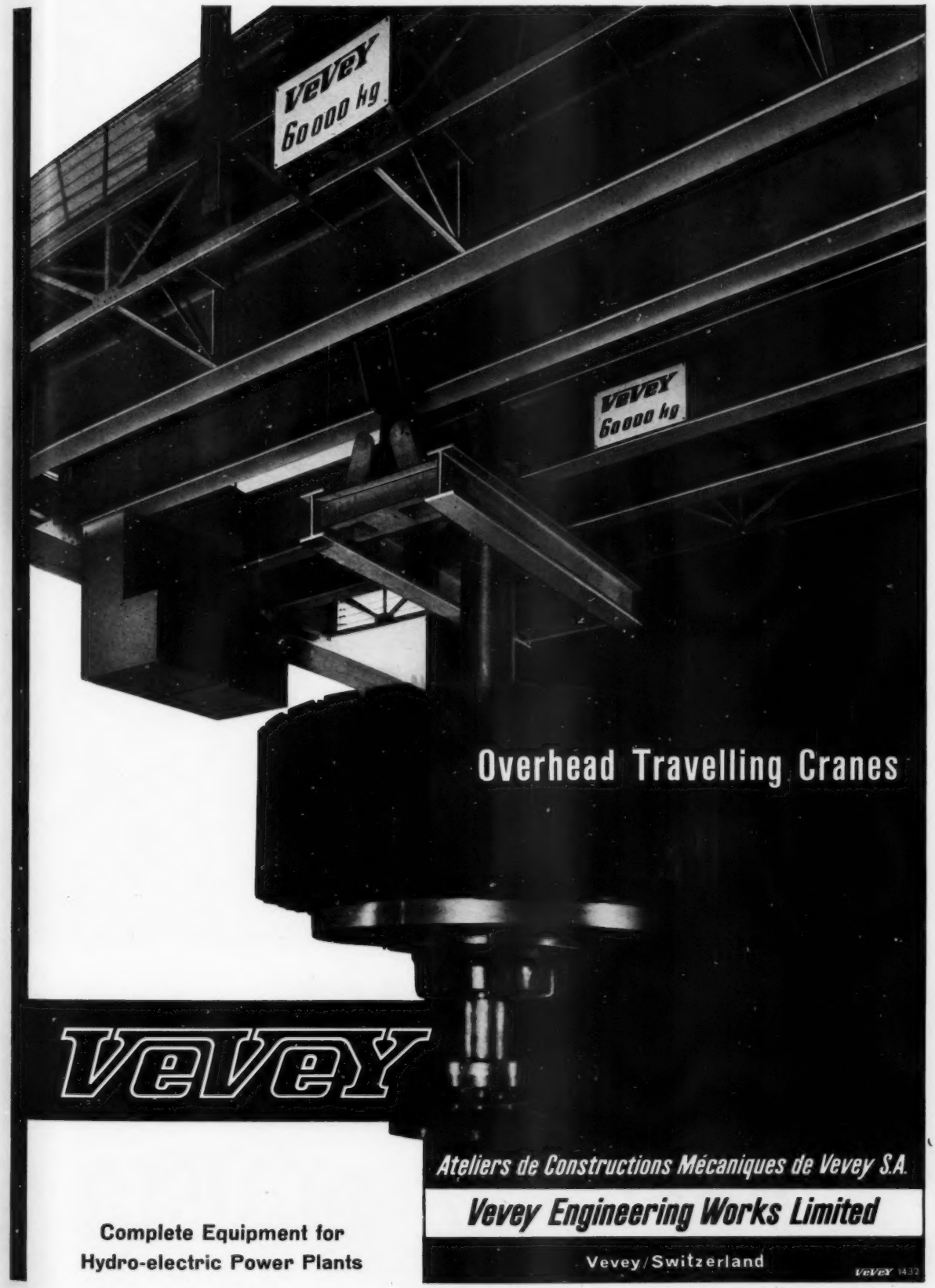
VeVeY
60000 kg
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Overhead Travelling Cranes
VeVeY
Ateliers de Constructions Mécaniques de Vevey S.A.
Vevey Engineering Works Limited
Vevey/Switzerland
VeVeY 1432
Complete Equipment for
Hydro-electric Power Plants

POWER BEHIND THE PUMP

This 600 h.p. Vertical Slip-ring Motor is an interesting example of a machine from the Brush range. It has been installed at the Table Bay power station, where it drives a pump at 485 r.p.m. from a 6,000 volt 3 phase 50 cycle supply. Brush motors are built to meet all applications, with outputs from 1 to 1,500 h.p.

If you have an electric motor problem, our knowledge and resources are at your disposal.

Vertical motors by **BRUSH**

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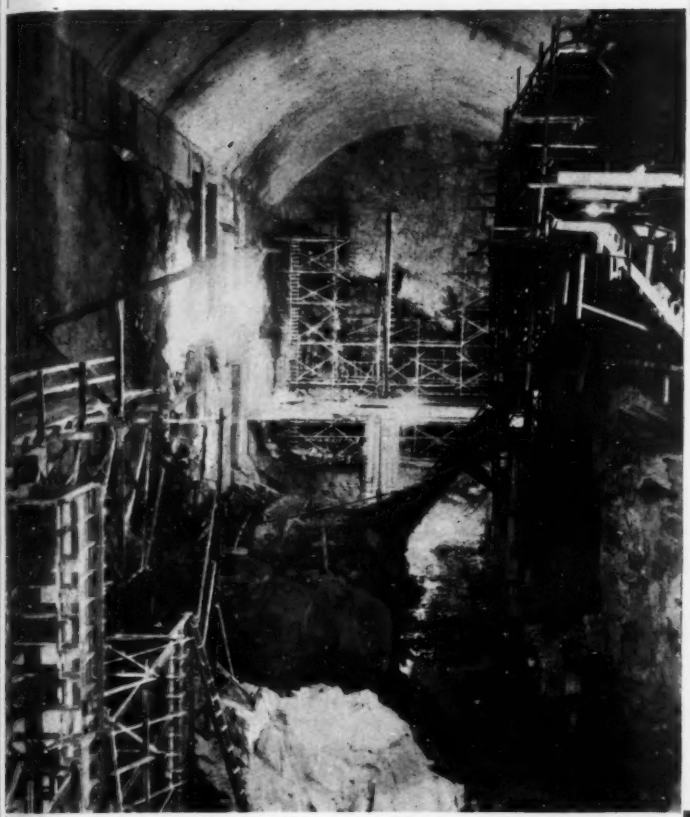
B13

FORÇACAVA
330,000 K.W. POWER STATION
BRAZIL



THE UNDERGROUND POWER CAVERN

LENGTH	116 M
WIDTH	20 M
HEIGHT	30 M

THE PENSTOCK SHAFT

SECTIONAL AREA .	44 M^2
TOTAL LENGTH .	520 M
LENGTH OF SLOPE	410 M
DEGREE OF SLOPE	42°

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CIVIL ENGINEERS
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THE ROCK EXCAVATION
OF
THE POWER CAVERN
AND
THE PENSTOCK SHAFT
EXECUTED BY
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BY USE OF
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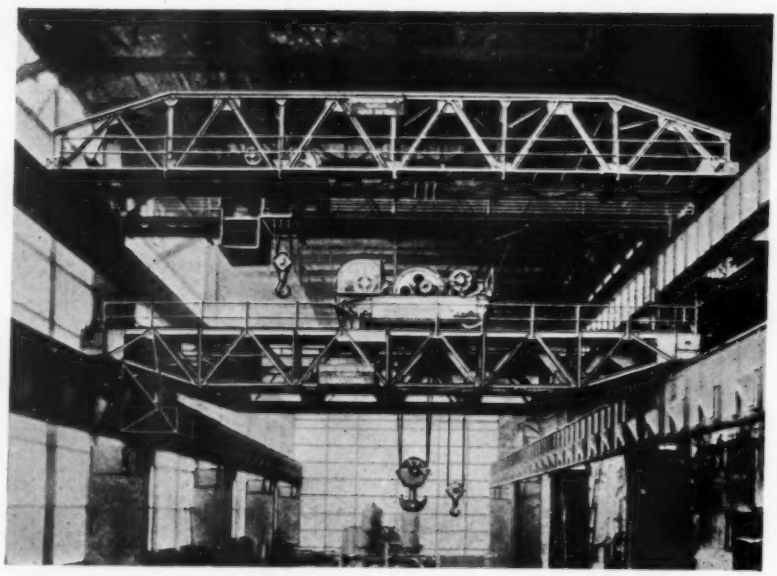
SENTAB

Arrol:

build many cranes. Their name-plate appears on the tallest tower cranes; the largest cranes (of 300 tons capacity) in any forge; the best designed steelworks cranes.

Cranes

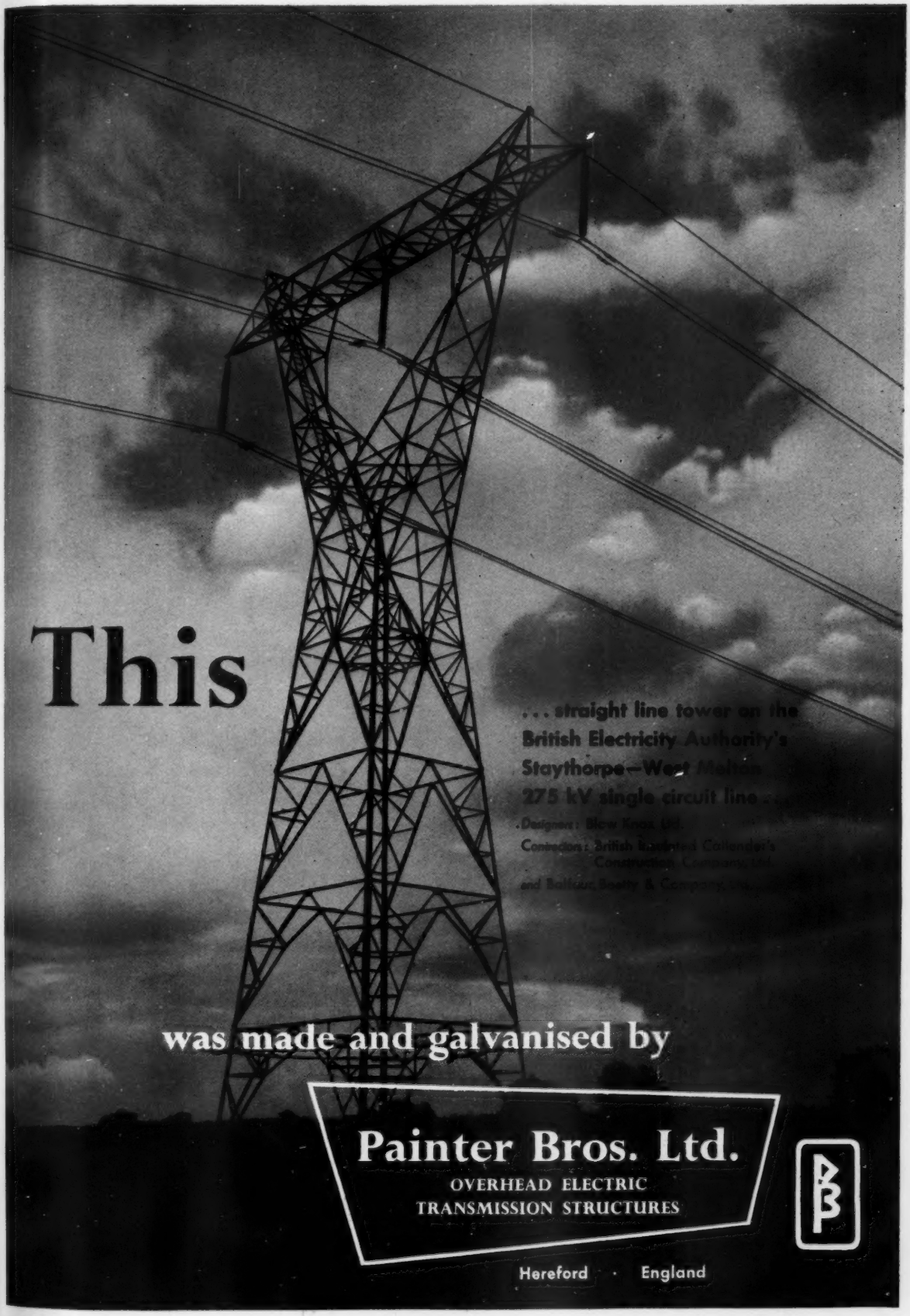


Two Arrol Overhead Electric Travelling Cranes installed in a power station. Capacities are 175 tons and 30 tons, the former being provided with auxiliary hoisting also.

and:

All types of Steel Framed Buildings, Fixed and Opening Bridges, Cranes and Mechanical Engineering Work, Dock Gates, Sliding and Floating Caissons, Compressed Air Locks, Hydraulic Machinery, Pipe Lines, Surge Tanks, Sluices and other equipment for Hydro-Electric Stations.

SIR WILLIAM ARROL & CO. LTD., GLASGOW


This
. . . straight line tower on the
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Staythorpe–West Melton
275 kV single circuit line
was made and galvanised by
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OVERHEAD ELECTRIC
TRANSMISSION STRUCTURES
Hereford · England

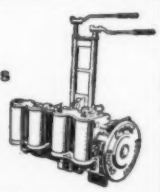
Onions Scrapers are way ahead

The 13 cu. yd. Onions Scraper in action with the Vickers VR·180 Tractor

9 cu. yd. Onions Scraper.

Onions Scrapers are made in 3, 4, 6, 9, 13 and 20 cu. yd. sizes. Tractors equipped with Onions Scrapers give faster production and lower operating costs. 6 cu. yd. models and over are equipped with a 3-piece cutting edge tipped with wear resisting alloy; two sets of end pieces are provided for either digging or levelling.

ONIONS CONTROL UNITS for finger-tip control of heavy earth-moving equipment.



AN ONIONS RIPPER— another leading design in earth-moving equipment. Available in sizes to suit all tractors.

These features put Onions Scrapers ahead of their field:—

- *Lightweight combined with tough construction.*
- *Ample tyre equipment, including extra large rear tyres for maximum flotation.*
- *Stability — the rear wheels are set to almost the full width of the cutting edge.*
- *Light to operate — central thrust tail gate and high lift apron for easy dumping.*
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World Distributors of Onions Scrapers, Power Control Units and Rippers

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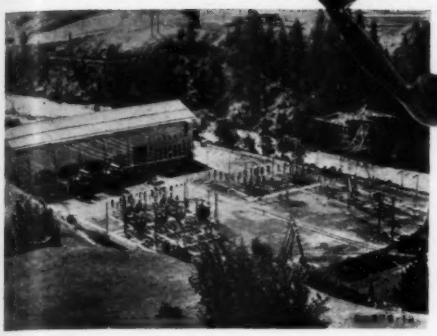
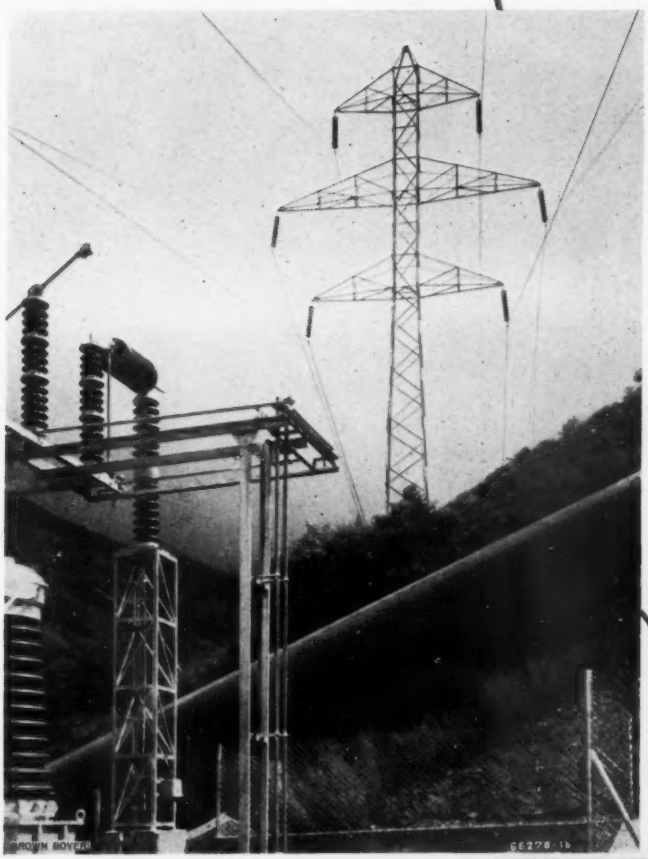
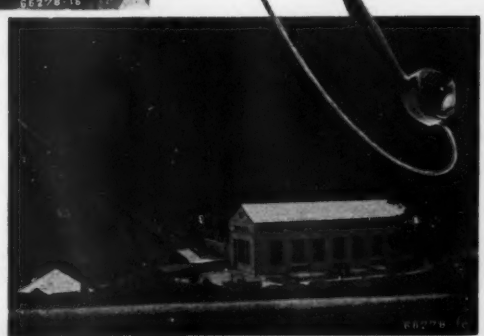




Coupling equipment of a carrier telephony transmission at the Mörel power station (Switzerland). 500-A double-wave trap and associated coupling capacitor mounted on a special frame in the outdoor switching station. This carrier link, superimposed on the 150-kV transmission line over the Nufenen Pass, permits telephone communication between the Mörel and Lucendro power stations.



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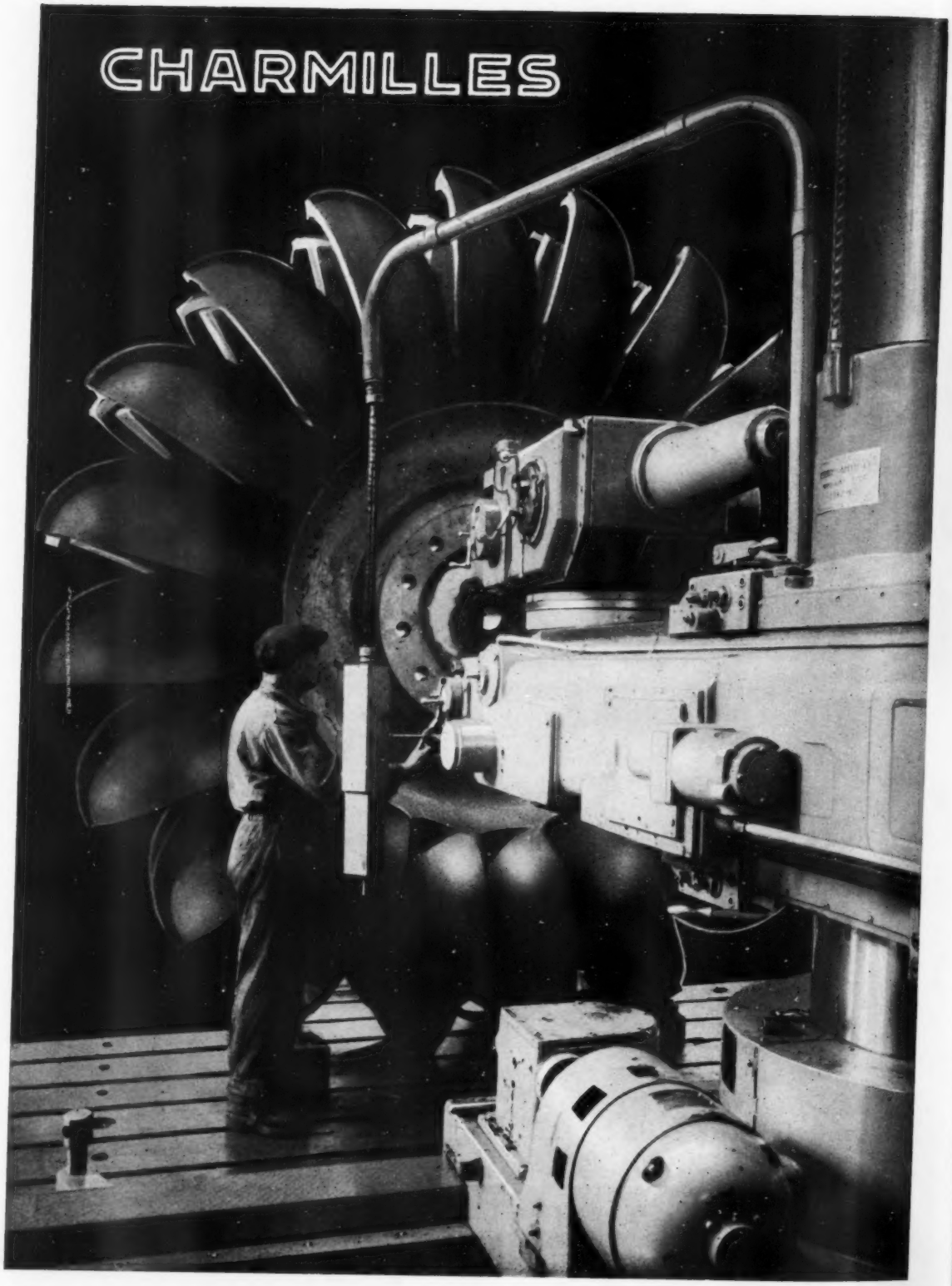

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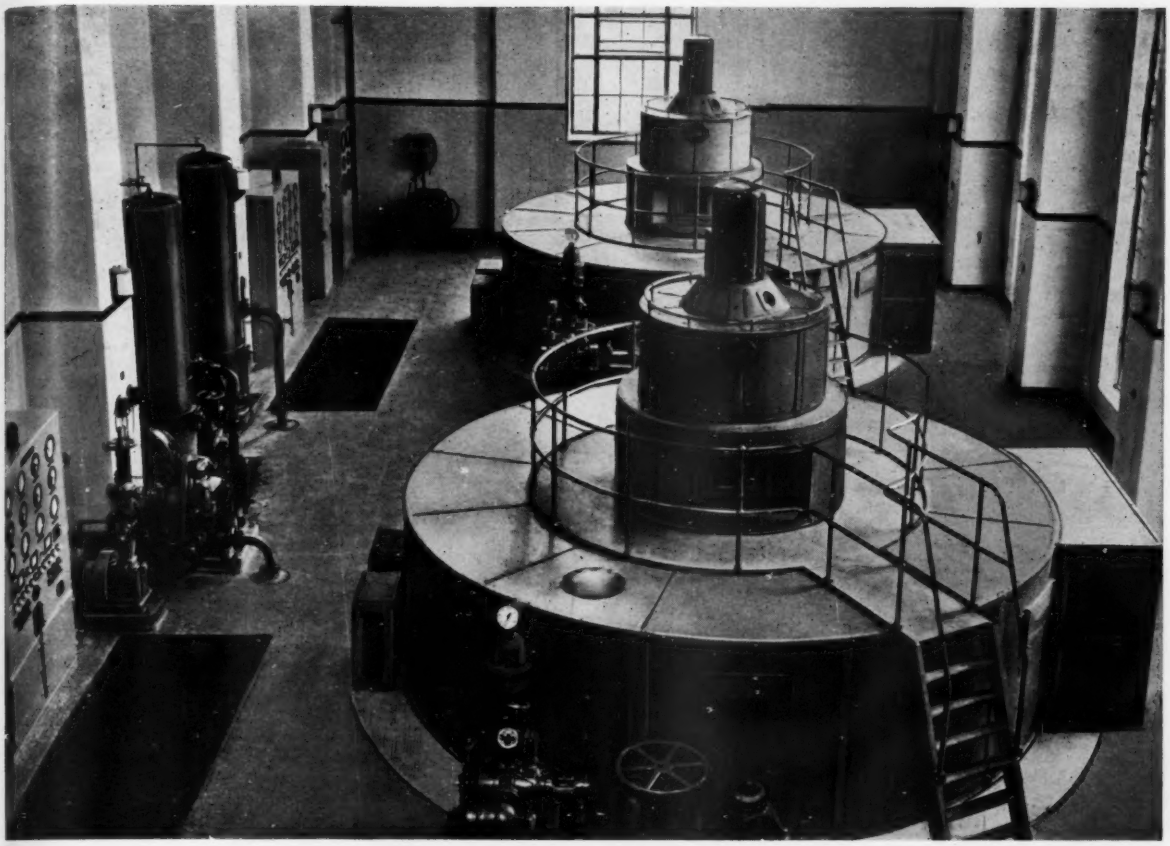
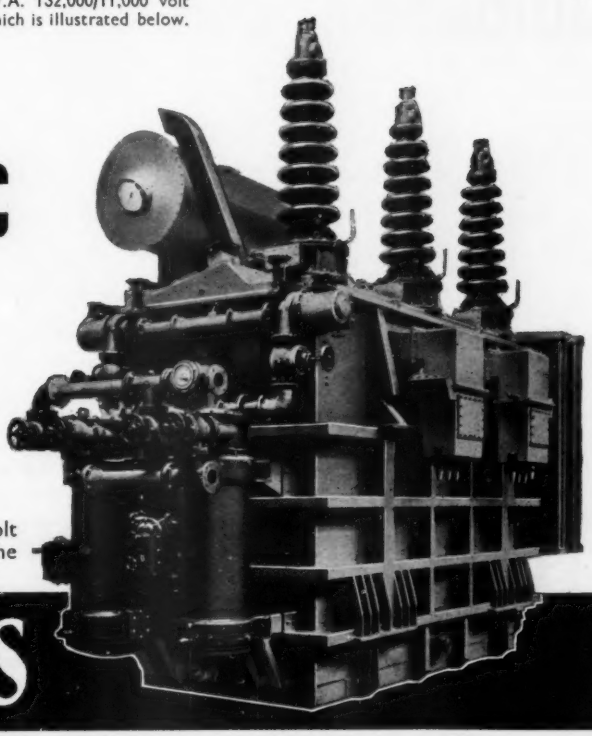


LOCH FANNICH PROJECT, North of Scotland Hydro-Electric Board. View of Grudie Bridge power station showing two 12,000 K.W. 11,000 volt, 500 r.p.m. vertical generators. The installation includes two 20,000 K.V.A. 132,000/11,000 volt water-cooled transformers, one of which is illustrated below.

PEEBLES

hydro-electric plant

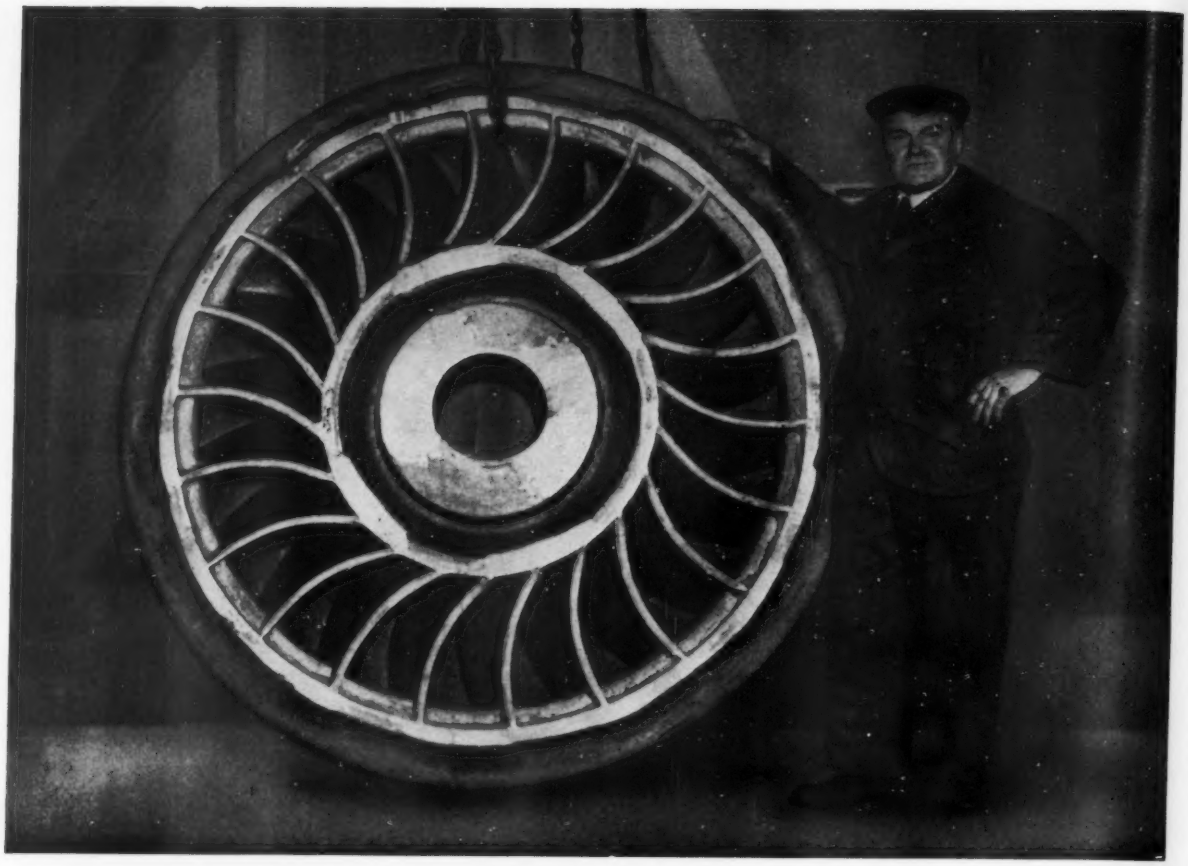
Bruce Peebles build large and small generators for all types of water turbines, and transformers up to the largest sizes for hydro-electric power distribution.



20,000 kVA. 132,000/11,000 volt water-cooled transformer for the Loch Fannich scheme.

BRUCE PEEBLES

Advertisement of BRUCE PEEBLES & CO. LTD. · ENGINEERS · EDINBURGH · SCOTLAND 3974



Aluminium-bronze for a tough job

Messrs. Gilbert Gilkes & Gordon Ltd., of Kendal, wanted a Turbine Runner Casting for a 3,600 H.P. Turgo Impulse Wheel and they specified a "BIRSO" Aluminium-bronze Casting. The specification covers a tensile strength of 45 tons per square inch, and a high resistance to erosion, corrosion and abrasion is called for. Aluminium-bronze is also guaranteed to withstand any hydraulic pressure.

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Phone: Stoke-on-Trent 2184-5-6 Grams: Birkett, Hanley

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Phone: Stoke-on-Trent 87303-4 & 88147 Grams: Bronze, 'Phone, Longport

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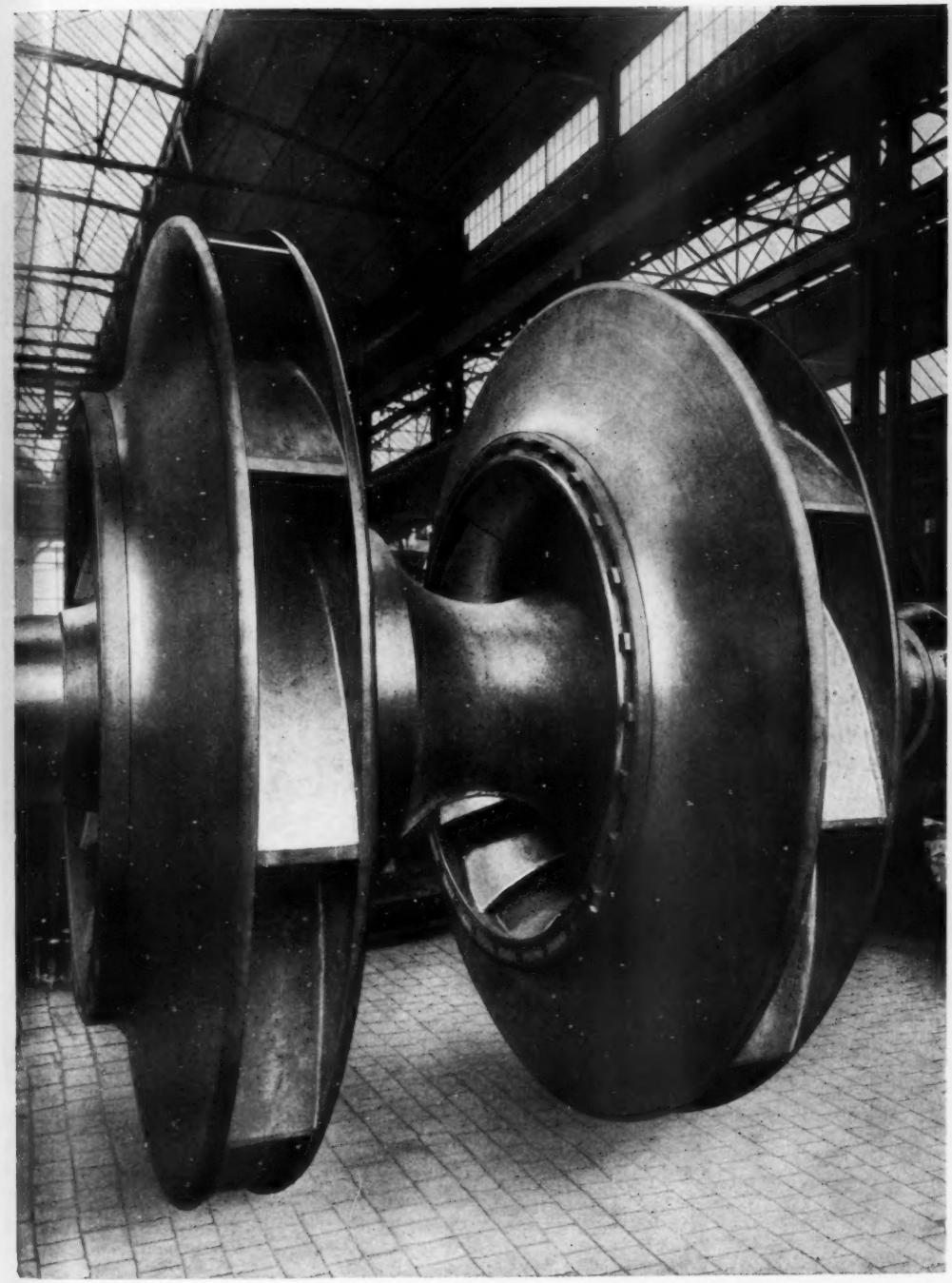


ESCHER WYSS ZURICH

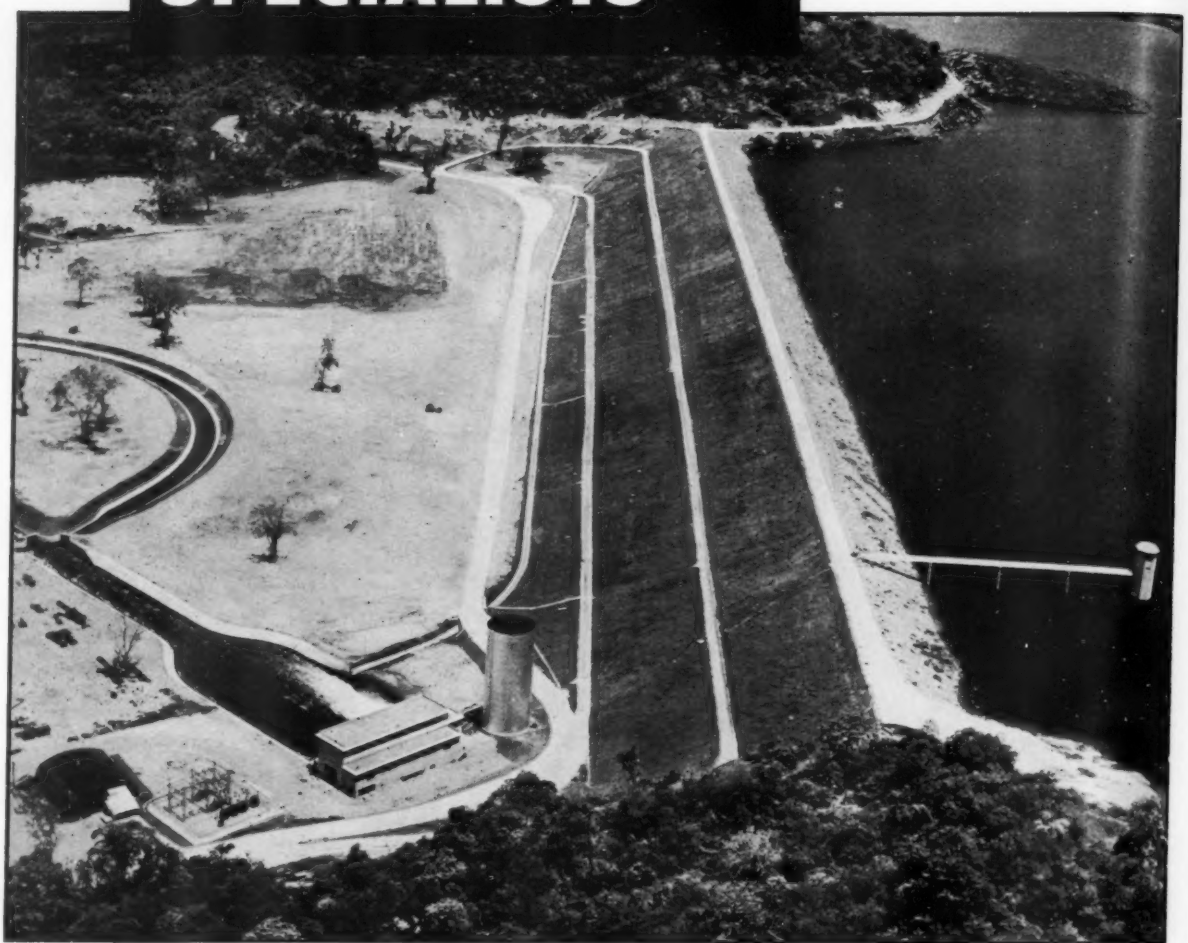
One of four two-stage storage pumps supplied by Escher Wyss, each discharging against a manometric head of 248 to 272 metres with a power input of 39100 to 34600 H.P. We have supplied such storage pumps with up to 60100 H.P. input per unit for discharging 14200 lit/sec. against a manometric delivery head of 270 metres.

Escher Wyss further specialize in Kaplan, Francis and Impulse turbines up to the largest outputs and heads, as also in other hydraulic equipment.

Our experience in manufacture and in installation work all over the world is at your disposal.

ESCHER WYSS LTD., ZURICH (SWITZERLAND)

WATER POWER SPECIALISTS



GAL OYA DAM, Ceylon — completed 1952 for hydroelectric power, flood control, irrigation. 3400 ft. long; 125 ft. high.

Harnessing water power has been a speciality of the Morrison-Knudsen organization for more than 40 years. The skill and experience accumulated over these years is your assurance of the efficient planning and competent execution so essential for the successful completion of large-scale water power developments.

Through International Engineering Company, a Morrison-Knudsen subsidiary, this experience is available to you for the design and construction of hydroelectric schemes and irrigation projects in any part of the world.

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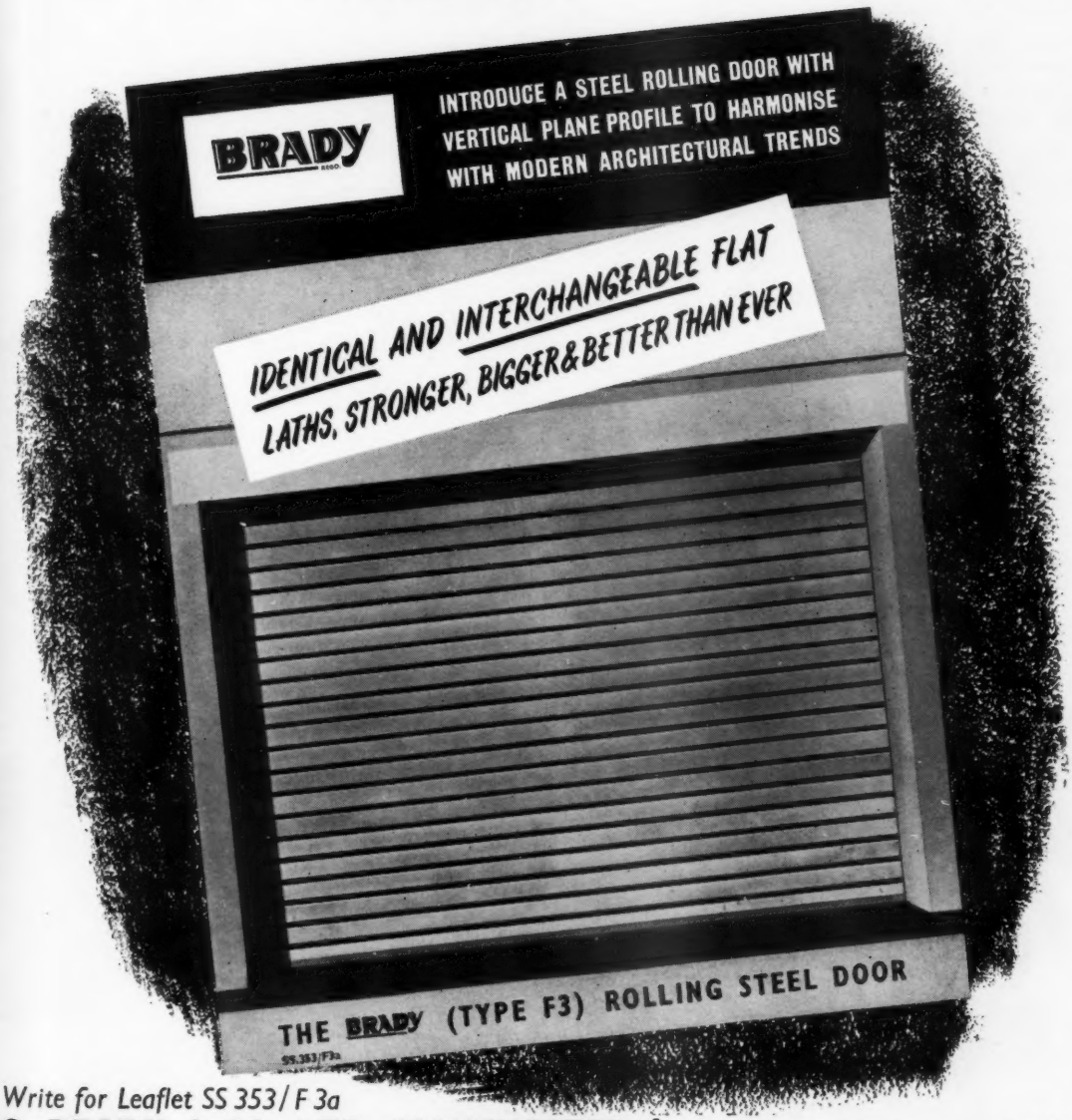
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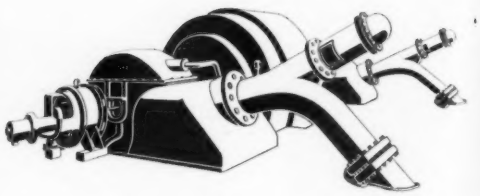

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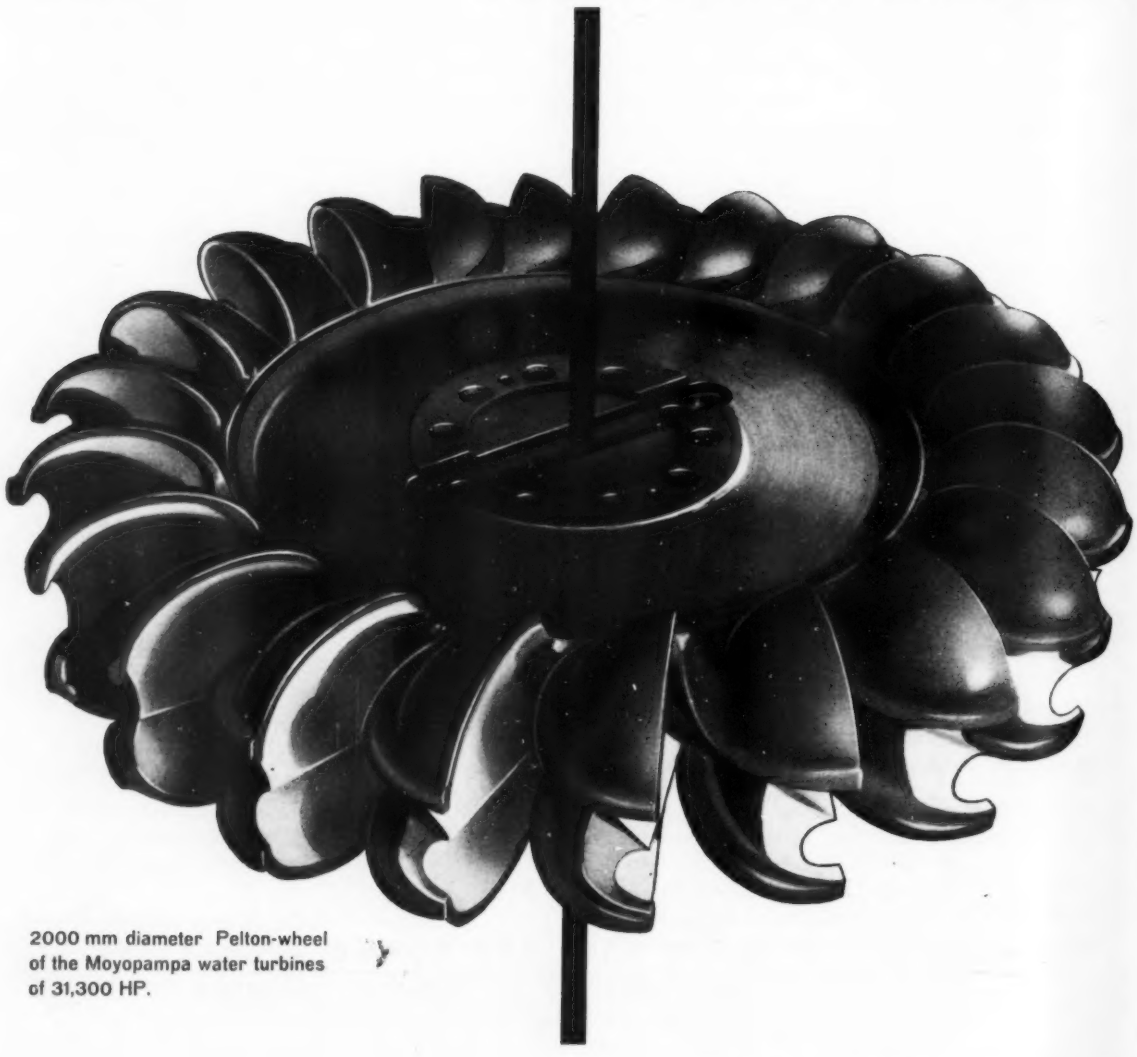

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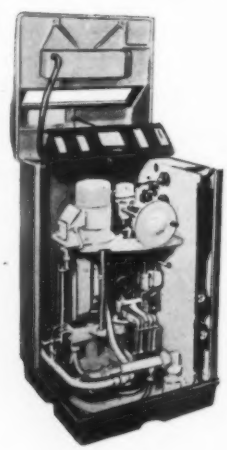

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Illustration.
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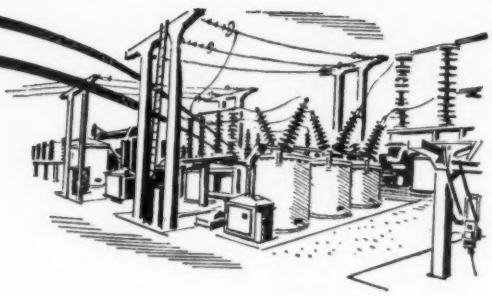

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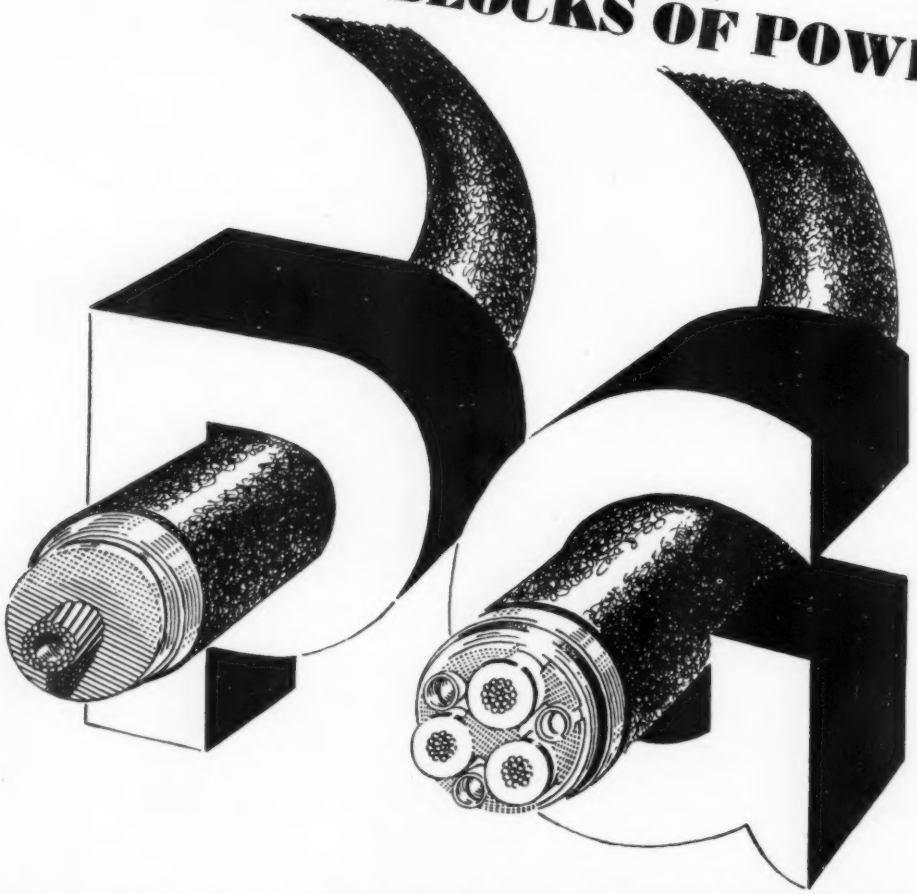

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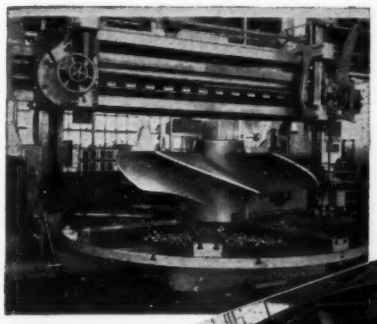
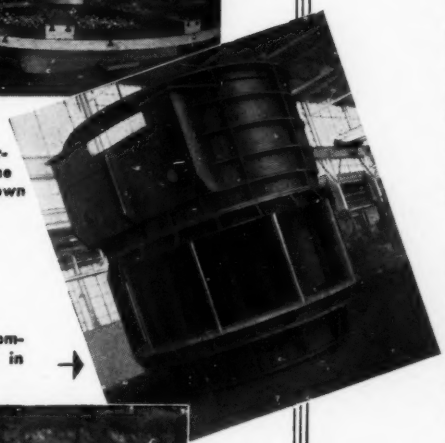
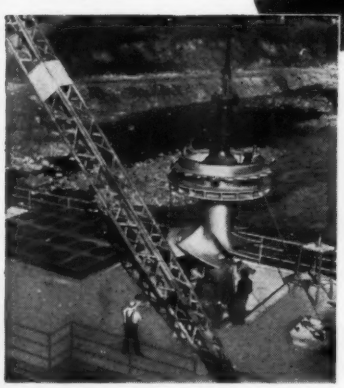


Cast steel propeller-type runner for the Wilbur turbine, shown on boring mill.



Wilbur turbine, completely assembled in the Leffel plant.



Lifting the combined runner, shaft and coverplate during the field installation.

The Wilbur power project of the TVA is another instance where a Leffel hydraulic turbine was used for the expansion of existing power facilities. For the Wilbur installation a Leffel vertical propeller-type hydraulic turbine was used — maximum rated at 11,500 HP, under 67 feet net head, speed 180 RPM.

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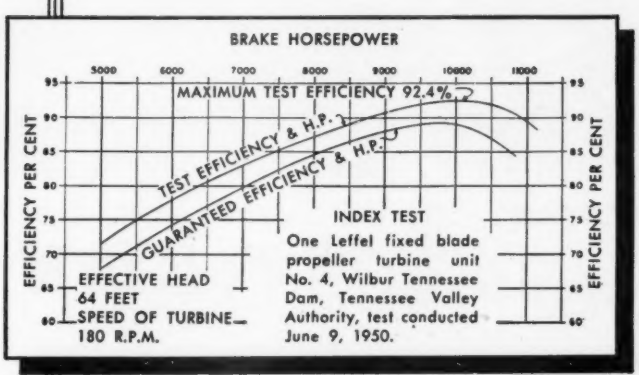

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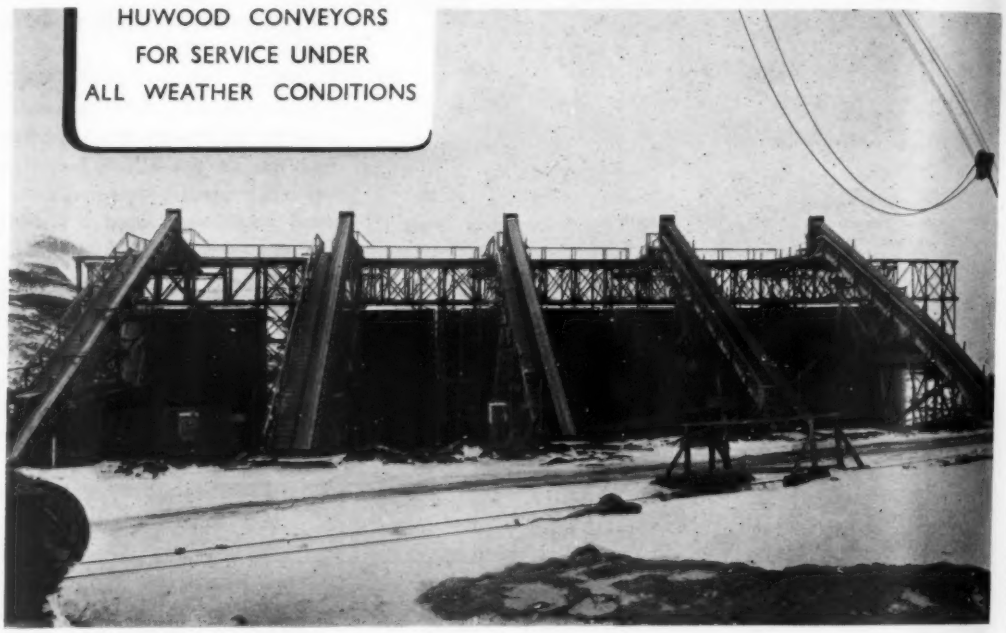

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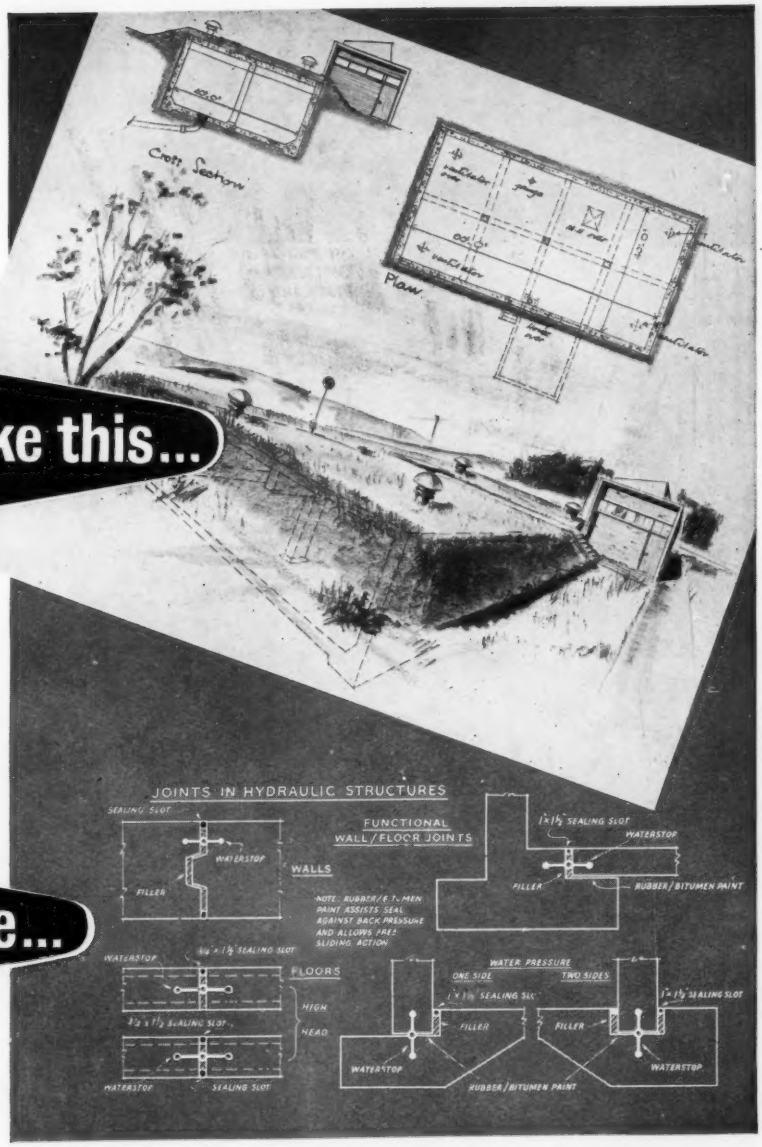

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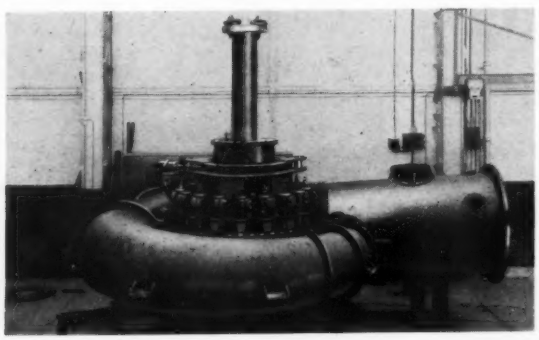

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CONTENTS FOR NOVEMBER, 1953

Editorial: Automatic Hydro-Electric Stations - - 399

Editorial Notes - - - - - - 400

The Juan Carosio-Moyopampa Power Station—I - 402

Correspondence: The Salanfe Project — Single-Jet Pelton Turbines - - - - - - 409

Anderson Ranch Dam and Power Plant - - 410
By D. L. Goodman

Minnesota International Hydraulics Convention—I - 422

Book Reviews - - - - - - 428

The Forçacava Hydro-Electric Scheme—III - - 429
By Prof. Dr. Techn. L. v. Rabcewicz

Brush Company's New Switchgear Factory - - 436

Portable Jack for Prestressing Concrete - - 437

General Electric Company, Schenectady - - 437

Abstracts from the World Technical Press - - 438

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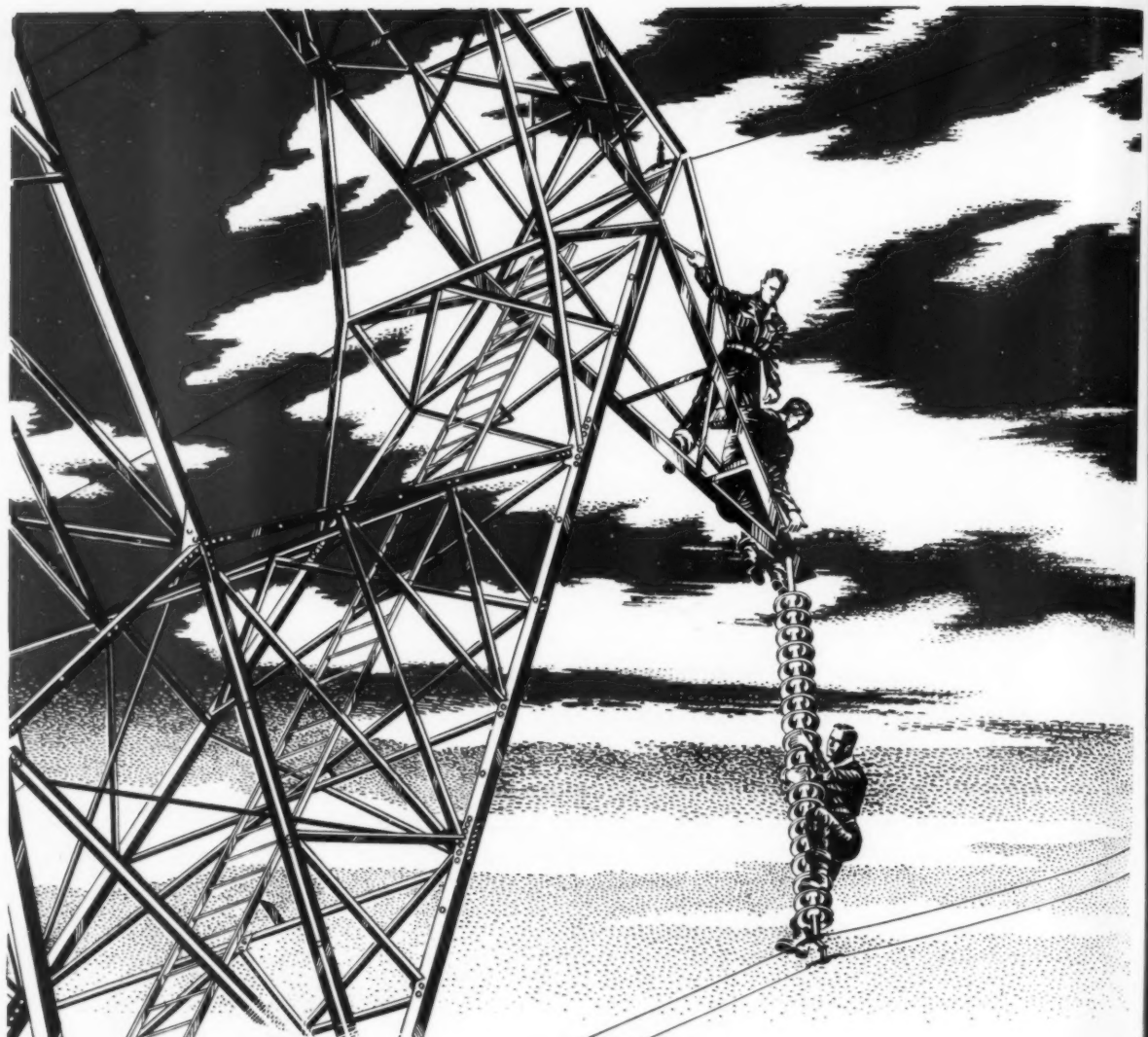

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Automatic Hydro-Electric Stations

THE electrical power engineer, in recent years, has begun to accept (still, perhaps, with caution) the electronic tube as being a component of his plant which may be regarded as reliable as, for example, a pressure gauge. Our steam-power-station friends have their troubles with turbine shafts which warp and expand beyond safe limits, and nowadays they are beginning to run their large sets with complete faith in the indications of the eccentricity meter and the expansion indicator, both fed electronically.

While the steam power station can never be operated without skilled personnel in close attendance, the hydro-electric engineer is beginning to be quite content to leave even the largest set running by itself; and this relatively new faith in the virtues of the electronic tube now enables him to visualise a whole new vista of completely unattended power plants, started up, controlled, and stopped, over carrier circuits on the main transmission lines.

Our fellow workers in another field of science have been developing the transistor and the germanium rectifier to a point where such devices can act as efficiently as thermionic tubes but without the fragility associated with glass envelopes and without the ageing effect of a diminishing output from heated cathodes.

Conventional-type tubes have been "ruggedised," in connection with such violent uses as guided missiles and high-altitude rockets, where they have to withstand the fearsome impact of the firing charges. Other types of tubes have been made suitable for use in submerged repeaters in cables for telecommunication purposes, left at the bottom of the ocean with no possible chance of replacement if failure occurs! Such tubes have given an extremely satisfactory account of themselves in long service.

It is very natural that an engineer responsible for the operation of a hydro-electric plant costing perhaps several million pounds will wish to take every possible precaution against maloperation, since almost uncontrollable forces may be unleashed in the event of failure of a vital element. He may decide to put his trust only in well-tried devices which are operated under constant supervision, but in so doing he may encounter at least two problems. First, he may not be able to induce men to live and work in the remote districts where hydro-electric potential is often to be found, and even if the technicians themselves were prepared to live near the station, their wives and especially their children, could not be cut off from the amenities which they have a right to enjoy.

Secondly, the high wages payable to skilled personnel, when capitalised, may well militate against the economic harnessing of the smaller streams, say up to 10,000 h.p. The balance between an economic project and one which cannot be justified may well be swayed entirely by labour-cost considerations.

It took at least twenty years before a steam-power-station engineer would put his faith in the electronic tube for operating purposes, as distinct from indication. Admittedly, the tube itself was undergoing development at a rapid rate during this period, but even twenty years ago tubes operated under supervision, such as those in broadcasting stations, were known to have several years of completely satisfactory life. It should not take as long as this for alert hydro-electric engineers to realise that by taking advantage of the latest electronic practice they can now plan completely unattended stations of any size, with the greatest possible confidence. They can also contemplate the design of "packaged" stations for the smaller projects, where the whole of the control equipment is built in and automatically coupled to the supply line as it is installed, the remote control end being in an attended load-despatching centre.

Electronically operated governors have already been used in Sweden and elsewhere for large hydro-electric sets, and information has reached us that they have not only given entire satisfaction but have also resulted in a closer degree of regulation. Electronic devices can measure water levels in reservoirs without the need for moving parts, and they are unaffected by ice and other natural hazards. Exact measurements of bearing temperatures, gate openings, speeds of auxiliary plant, oil pressures, and the like can readily be transmitted, and electronic equipment can also keep an even closer check than the human operator

on such operating characteristics as vibration, water hammer, leakage in deep pits, the presence of debris coming down the river hours before it reaches the trash screens, and many other features of hydro-electric power station operation.

Tube circuits may be made to "fail to safety," as the railwayman says, and duplicate tube circuits can be brought into commission automatically. Jack-in panels can be arranged so that an unskilled worker can remove a whole section and replace it with a new and tested reserve unit, the other then being returned to a distant workshop for skilled maintenance. Carrier circuits over the power lines can be so arranged that if line failure occurs, an automatic switchover to short-wave radio is effected.

In the past, the hydro-electric engineer has been among the most conservative of his brethren. The very few plant failures which have occurred in recent years have paid tribute, perhaps indirectly, to his caution and care both in the selection of equipment and in its operation and maintenance. And while no one would wish that this care and caution should be relaxed to the slightest degree, the electronic engineer can now, with absolute confidence, offer him a tool that can be of the greatest possible assistance to him, in the safe and economic operation of his plants.

World Power Conference Brazil Meeting

ARRANGEMENTS for the Sectional Meeting of the World Power Conference to be held in Brazil from July 25 to August 8, 1954, are going steadily ahead, and the definitive text of the technical programme appears in the Annual Report of the World Power Conference, 1952, which has just been published. The general theme of the meeting will be power problems in tropical and subtropical regions. Hydro-electric plants will be considered both in this context and in their relation to thermal plants, and there will also be sections on wind power and on solar energy.

Fifth Congress on Large Dams

THE World Power Conference Annual Report referred to in our previous note also contains some particulars of the Fifth Congress on Large Dams to be held in Paris in 1955. Questions to be included in the programme are: Design and construction of dams on permeable soils and methods of foundation treatment; economics and safety of different types of concrete dams; settlement of dams due to the compressibility of the dam materials or of the foundation soil, including earthquake problems; and the relation of the cement content of the concrete to performance in practice of gravity, arch and buttress dams. The question of testing on small-scale models will not be included in the programme of the Congress, but communications will be invited for publication in a bulletin.

Preparations are in hand for a second edition of the Technical Dictionary of Dams.

Further Rio Grande Plant

CONSIDERATION is now being given to further development in the Rio Grande, near Medellin, in Columbia, representing the second stage in the harnessing of this river for power purposes. In the first stage the installation called for 70,000 kW of capacity and work on this stage is well advanced, funds having been provided from American sources. It is hoped to finance the second stage, which is estimated to cost 14 million pesos, from local sources and it is probable that some of the equipment will be purchased from Europe. Actual work on the second stage is expected to begin in 1954.

Volta River Policy

THE Gold Coast Minister of Commerce, Mr. K. A. Gbedemah, said in London recently that it was not proposed to give preference to British equipment for the Volta River project although it might be partly financed by a loan from the British Government. It will be recollected that a scheme was prepared by Sir William Halcrow and Partners and embodied in a White Paper published last December. The development is estimated to cost £144 million and to develop 564 MW of firm power, most of which would be used to produce 210,000 tons of aluminium per annum.

Swedish Power Needs

DURING 1952 Swedish water-power plants produced about 20,000 million kWh. This means that the country has taken into use approximately one-third of all the hydraulic power that is technically and economically exploitable. Power demands, however, are rapidly increasing; the annual rise in consumption is at present 1,200 million kWh, but from 1957 and onwards it will probably be 1,500 million kWh per year. The new power plant at Stornorrfors outside Umea in Norrland, which will have an annual output of 2,200 million kWh—some 200 million kWh more than the large Harsprånget plant above the Arctic Circle, inaugurated last year—will meet the increase in consumption for only 16 months when taken into use by the end of the 1950's. Yet it involves an investment of Kr. 200,000,000 (£13,800,000). The Swedish power industry invests considerable amounts in new plants. Present estimates show that during 1953 Kr. 2,000,000 (£137,900) will be invested every working day.

British Equipment for Spain

AT the recent 21st Barcelona International Samples Fair, the British Official Pavilion was the first of its kind at fairs in Spain. The Ambassador, Sir John Balfour, at the special Coronation lunch of the British Chamber of Commerce, referred to the official participation of the United Kingdom in the Fair as showing recognition of the importance of Spain as a traditional market for British goods, and the part being played by British equipment and initiative in the network of reservoirs and hydro-electric plants being developed by the Spanish Government. In connection with various hydro-electric systems under construction in Spain, Metropolitan-Vickers is supplying a large quantity of generators, switchgear, transformers, and other electrical equipment, including waterwheel synchronous condensers. Outstanding in point of size are three 75,000 kVA 214 r.p.m. generators for San Estaban, on the Saltos de Sil S.A. network. The associated switchgear consists of seven 220 kV 3,500 MVA air-blast circuit-breaker units,

and the transformers comprise three 75 MVA 15/214 kV groups. Three 15,000 kVA generators for the same network will be installed in the Escales Falls power station. Large synchronous condensers in hand, together with their associated switch and control gear, include two of 30,000 kVA for Saltos del Sil (Madrid substation), three of the same rating for the Electra de Viesgo S.A. (Puente San Miguel and Mataporquera substations), the first of which is now being erected, and two of 20,000 kVA for Iberduero S.A.

Waikato River Scheme

THE Government of New Zealand have decided that an early start shall be made on the Atiamuri project on the Waikato River. It is proposed to erect a 125 ft. high dam near the Atiamuri bridge and to build a power station of 63,000 kW capacity. Three Francis-type units will be installed and will normally operate on a head of 83 ft. The design of the scheme has been entrusted to Sir Alexander Gibb & Partners and will be the fifth hydro-electric project on the Waikato River.

Lussa Station Inaugurated

THE Lussa station supplying the Kintyre peninsula in Argyll was formally opened last September by Mr. Thomas Johnston, chairman of the North of Scotland Hydro-Electric Board. It contains two 1,200 kW sets operating under a head of 380 ft., the first of which has been in service since February 1952. Originally the scheme had a catchment area of 13 square miles, the waters being impounded by a concrete dam 260 ft. long and 40 ft. high, having a central arched portion 160 ft. long. In April 1952 an extension scheme was announced which will increase the catchment area and bring the annual average output to 10¾ million kWh.

Orange River Plan

AT the opening of the Natal Agricultural Union Congress at Pietermaritzburg, a water conservation and hydro-electric scheme on the upper waters of the Orange River in Basutoland was foreshadowed by Sir John Le Rougetel, the United Kingdom High Commissioner. It was hoped, he said, to dam the Orange and Senqunyane Rivers at Seforong, where a basalt reef crossed the gorge 500 ft. deep. If this were done it would establish a reservoir 90 miles long that would take eight years to fill. The water could be used to supply plant on the main dam and at smaller dams farther down the Orange River totalling 150 MW.

World's Largest Dam Projected

A MULTIPLE-PURPOSE scheme is now being planned for California which will include the largest dam in the world. This will be on the Feather River at Oroville. It will have a crest length of 6,850 ft., a height above stream bed of 710 ft., and will require 14 million cubic yards of concrete—40 per cent. more than that used in the Grand Coulee dam and twice that in the Shasta dam. A spillway, 810 ft. long, will be located in a saddle on the right abutment, joined to the main dam by a 1,000 ft. earthfill section. The storage capacity will be three and a half million acre feet. A 440 MW power station will be located at the foot of the dam, and a 25 MW station will be built below a secondary dam about 4½ miles downstream.

An extensive system of tunnels, canals and pumping stations will transfer Feather River water to areas in San Francisco Bay, San Joaquin Valley and Southern California.

Grande-Dixence Progress

IT is two years since the preliminary work on this new dam in the Canton Valais was begun and the first lift of concrete has now been placed. It will be recalled that this structure will be the highest of its kind in Europe and will have an ultimate height of 927 ft. The older dam, higher upstream, will be completely inundated by the new reservoir that will be formed and which will have a capacity of 1,320 million cubic feet. A further period of sixteen years is likely to elapse before this great scheme is completed.

Gediz River Scheme

WORK is to commence next spring on a hydro-electric plant at Demirköprä on the Gediz River, Turkey, which will supply 152 million kWh per annum in addition to controlling floods and providing water for irrigation. A 246 ft. dam will provide a storage of 900,000 acre feet, and the power station will be located about two miles downstream. There will be 174 miles of 154 kV line and 40 miles of 33 kV line. Construction is expected to occupy three years, and the total cost will be of the order of £18 million.

Rainmaking in Australia

ARTIFICIAL rainmaking is being studied in Australia by the Commonwealth Scientific and Industrial Research Organisation, and Dr. E. G. Bowen, who is in charge of the investigations, considers that rainfall could be increased by up to 50 per cent. over the marginal rainfall area extending inland from the Great Dividing Range in a belt 300 to 500 miles wide and 2,000 miles long. Falls ranging from one-quarter to three-quarters of an inch and lasting from 40 to 60 minutes have already been produced, and the present problem is not technical so much as economic. The study is evidently pursued with the object of improving agricultural conditions and not from the hydro-electric standpoint.

Iowa Hydraulics Conference Proceedings

The Proceedings of the Fifth Hydraulics Conference held in the summer of last year by the Iowa Institute of Hydraulic Research have now been published. The conference was devoted to the general subject of sediment transportation, and the 14 papers were divided into five groups: The Sediment Problem, Movement of Bed Load, Entrainment and Supervision, Scour and Deposition, and Measurement and Analysis. In the published Proceedings the papers are printed in full and the discussions summarised. It is our intention to publish abstracts of the papers in the near future, but copies of the full Proceedings can be obtained from the Institute at the State University of Iowa, Iowa City, price $3.50.

Fig. 1. Lake Sacsa dam, 4,400 m. above sea level, 16 million cu. m. storage capacity

The Juan Carosio-Moyopampa Power Station

A description of a Peruvian development in which a 42 MW station on the Rio Santa Eulalia provides much-needed power to Lima and district.

PART ONE

TO bridge the gap between a consumption that had not ceased to grow since 1934, and a production that had remained stationary owing to the impossibility of setting up new generating plants during the war, such was the problem that, upon the cessation of hostilities, confronted the Empresas Eléctricas Associadas S.A., the concessionaire for the supply of electric energy to Lima and district, better known in this country under its old style of Lima Light and Power Company.

The area catered for by the E.E.A. extends from the seaport of Callao, 12 km. west of Lima, through the lower valley of the Rimac to its confluence with the Rio Santa Eulalia, 45 km. east of the city and, through the Santa Eulalia valley, 20 km farther eastwards, to Autisha.

A first step in the solution of this urgent problem was the addition of a 10,000 kW Brown-Boveri gas turbine to the thermal plant of Santa Rosa de Lima; as a second step, it was decided, towards the end of 1946, to erect a new hydro-electric power station at Moyopampa, to be built and operated by a new company promoted for this purpose, the Hidrandina or, to give it its full name, the Energia Hidroeléctrica Andina S.A. Work on the construction of the new scheme promptly began in January 1947 and, in September 1951, the first 21,000 kW generating unit was put into commission, followed in March 1952 by a second unit. Since then, the Santa Rosa thermal plant has acted as a standby.

Local Conditions, Catchment Area and Hydrographic Data

The Moyopampa power station utilises a gross head of 500 m. available on the 13·6 km. stretch of the Rio Santa Eulalia between the Juan Carioso de Callahuanca plant and Chosica (Fig. 2), 400 km. east of Lima. The catchment rises up to 6,000 m. above sea level, but it is poor in glaciers, so that hardly half of its 1,200 sq. km. area contributes to the supply of power water; below 3,000 m. precipitation occurs only at long intervals.

Like the other rivers on the western slopes of the Andes, Rio Santa Eulalia has a continuous low-water period from April to November, and a relatively short high-water period from December to April which concurs with the rainy season in the higher Andes. The considerable reduction in the flow in the Andean rivers during the dry season unfavourably affects the coastal population, since vegetation

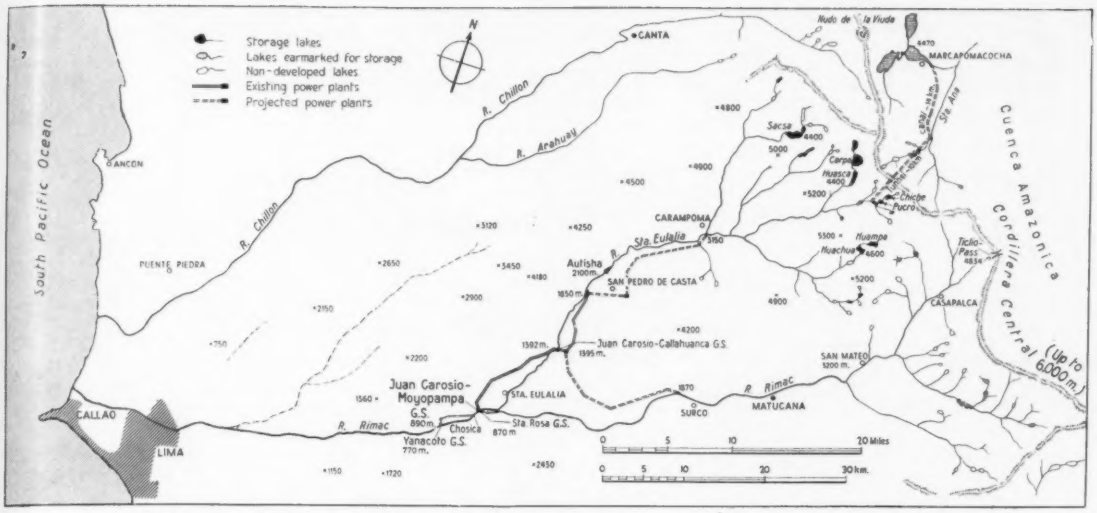


Fig. 2. Map of Rimac and Santa Eulalia basins showing existing and projected stations

in the lower region west of the Andes depends exclusively on artificial irrigation. Seeing that the Santa Eulalia is one of the main sources of water supply to Lima and the neighbouring districts, endeavours to boost its flow at low-water period date as far back as the last century, when emergency storage was provided in its basin by either lowering or raising the level of natural lakes existing at altitudes of 4,300 to 4,700 m. (see Fig. 1); about 20 years ago, when E.E.A. were completing their first major hydroplant on the Santa Eulalia, other natural lakes were developed so that a useful aggregate storage of 70 million cu. m. is now available in fifteen lakes. This resulted in an increase of the dry-season discharge from 1·5 to 4·5 and even 5 cu. m. per sec. A team of attendants, stationed on the right bank of the Puero lake, adjusts the outflow of these lakes according to radio-telephonic instructions issued from Lima.

Fig. 3. General view of Moyopampa intake works

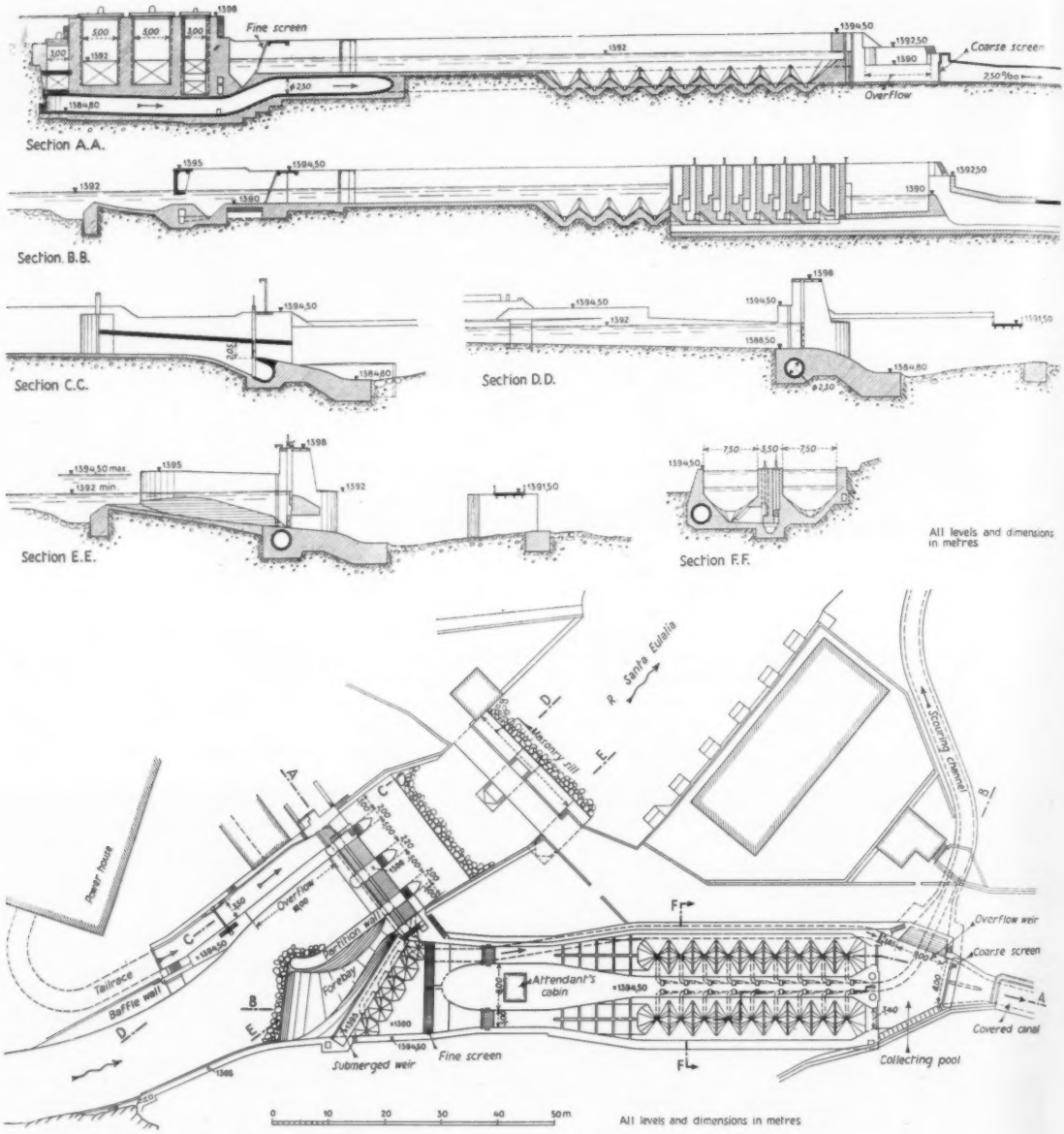


Fig. 4. Plan and sections of Moyopampa intake works, weir and sand traps

The territory just below the lake region is still awaiting development and the water, in so far as it is not absorbed by irrigation, flows in its natural bed as far as the Autisha storage basin (El. 2,100 m.). This basin acts as a daily and week-end compensation reservoir, and also corrects minor irregularities in the control of the reservoirs.

A slight improvement of the present rate of dry-season discharge could be achieved by harnessing further lakes for storage, but this would involve considerable expenditure. On the other hand, the diversion of rivers from other catchment areas into Rio Santa Eulalia would have much greater possibilities; this latter solution is being examined in two alternative projects:—

(a) Raising the level of the shallow Marcapomacocha lakes east of the Andes watershed in the catchment area of the Amazon (El. 4,470 m.), and diverting their water by means of a 14 km. aqueduct and a 10 km. tunnel traversing the range of the Andes;

(b) Diverting the Rio Rimac by means of a 20 km. tunnel at El. 1,850 m. to the surge tank of the Callahuanca plant above Moyopampa.

Once carried into effect, either of these two alternatives could about double the useful discharge of the Santa Eulalia during the whole of the dry season. Taking into account these two projects, of which the Rimac diversion is likely to be set up in not too distant a future, it appeared expedient to determine at the outset the ultimate extent of the Moyopampa

station with a view to enabling it to cope later with any additional discharge conveyed to its headrace.

Description of the Works

The main characteristics of the Moyopampa power station are as follows, the first figures given for each item applying to the initial stage, and the second to the final stage of development, which comprises the Rimac diversion:—

Catchment area	sq. km.	1,200	2,000
Rated discharge	cu. m. per sec.	10	16
Gross head	m.	500	500
Net head (at full load) ..	m.	460	460
Installed turbine output ..	h.p.	60,000	90,000
Installed generator output	kW	42,000	63,000
Number of generating units		2	3
Number of penstocks		2	3
Yearly production	M kWh	190	400

The initial stage can be considered as concluded. Intake works, delivery tunnels and surge tanks are designed for their ultimate duties. The supporting structures for the third penstock and the foundations of the third generating unit are ready for the erection of their respective equipment.

Intake Structures

The intake works are located on the tailrace of the Callahuanca plant. As the intermediate catchment area has no water supply available, the building of intake works could have been avoided without entailing any loss in energy production, but this economical solution was rejected because Lima depends for its current supply on but a few plants of the E.E.A., and the possibility of landslides, involving the fall of huge masses of rock into the river bed, can never be discarded in these regions at high-water periods, especially in the months of February and March. These "huaicos," as they are called in Peru, have indeed repeatedly caused stoppages in run-of-river plants.

In view of the torrential character of the high-water flow, special care had to be devoted to the design of the intake and desilting works, and these structures were the object of comprehensive model tests, carried out at the laboratory of the Federal Technical High School upon request of the authors of the project, the Motor-Columbus concern in Baden.

The layout of the intake is shown in Figs. 4 and 5, the weir is a four-gate construction, with two 5 m. waterways in the middle and a 3 m. opening on either side. A gate inserted in the tailrace of the Callahuanca plant enables the discharge from this plant either to be diverted to the delivery tunnel of the Moyopampa station through a culvert in the sill of the weir, or to be returned to the river. The weir opening of the forebay has two closure gates, a bottom outlet, and a desilting sluice. All gates, excepting the two last ones, are motor operated.

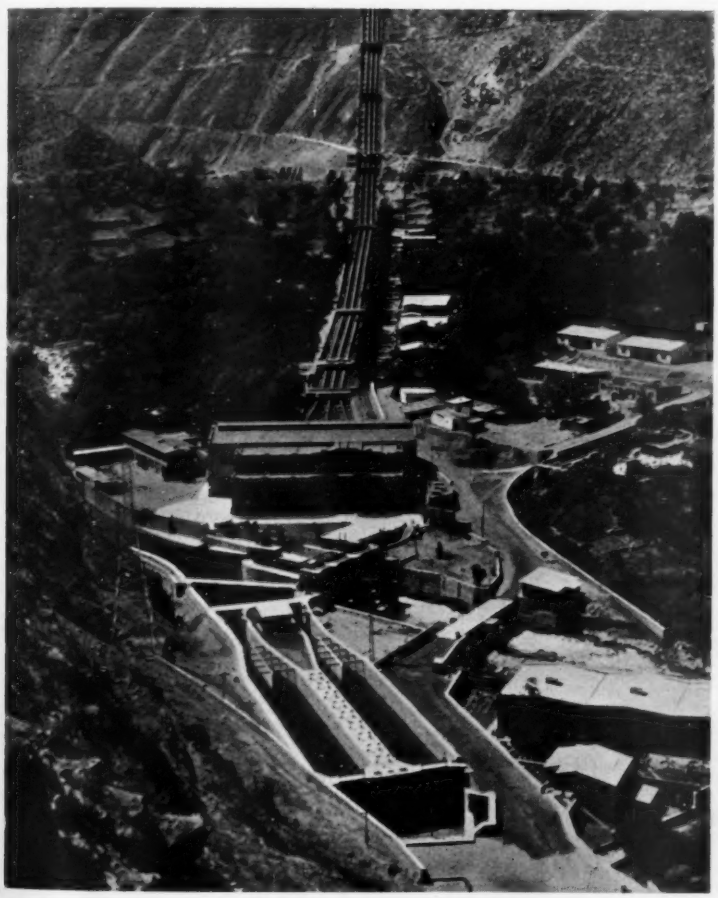


Fig. 5. Moyopampa weir and sand traps, with Callahuanca station in the background

The two middle waterways, with gates fully raised, can cope with the maximum discharge of 180 cu. m. per sec. without the normal water level at the weir (El. 1,392 m.) being exceeded. To guard against the results of incorrect handling of the gates or failures in their driving gear, an 18 m. long overflow weir is provided on the longitudinal wall of the Callahuanca tailrace. Owing to the steep gradient of the river bed (4 to 5 per cent.) shooting flow access in the undammed stretches, and at times of increasing discharge, the hydraulic jump at the upper end of the storage reach travels downstream as far as the downstream end of the forebay; this results in considerable water-level differences between the middle waterways and the forebay, which at highest-water periods may reach about 2·5 m. On account of these differences the height of the baffle wall was increased to El. 1,395 m. and reinforced concrete was used in its construction in order to meet the higher load carried on its wetted face.

Taking into consideration the observations made in the course of the model tests, the protective apron on the downstream

side of the weir is laid as deep as about 2 m. below the natural bed of the river, and because of the abundant drifting of solid matter, there is no upward gradient at its downstream end. In order, however, to ensure an adequate dissipation of energy and to avoid serious scouring, a sill, incorporating the pier of an existing bridge, has been set up, with its upper edge 1·4 m. higher than the apron, about 20 m. downstream from the weir. This very economical design has proved satisfactory.

A submerged flat-leaf gate is interposed in front of the sand-trap inlet, to stop drifting material, and coarse sand and gravel entering the forebay at high-water periods are cleared in a battery of five single-flushing settling hoppers, erected between the submerged gate and a fine trashrack with bars 38 mm. apart. Thence the flow narrows down in two 3 m. wide channels which are fitted with closing gates, and lead each to a battery of nine desilting hoppers designed for a discharge of 8 cu. m. per sec. each. These hoppers can be flushed separately through gates mounted in the pier between the two batteries. Under normal flow conditions, flushing is done intermittently, but at periods of high water, when there is much material in suspension, the flush-gates of the first two or three hoppers in each battery are left slightly open all the time.

The discharge of power water is regulated by gates at the downstream end of the desilting installation, the level of the water being the same in the sand traps as in the forebay, and varying therefore with the discharge of the river. This arrangement has the advantage of avoiding dissipation of energy at the sand-trap entrance, together with its detrimental effect on flow conditions; but this advantage could only be secured at a price, since the height of the walls included in the desilting installation had to be fixed in accordance with the highest water level occurring in the forebay, that is to say 2·5 m. above the normal storage level.

The sand trap channels connect downstream with a collecting pool, which also receives the water discharged by the upstream plant. In case of incorrect handling of the gates, a spillway evacuates excess water into the scouring channel, which returns it to the river. Otherwise, the power water, after passing a coarse trashrack, is conveyed to the delivery tunnel through a 55 m. long covered canal.

Fig. 7. Penstock in course of erection

Delivery Tunnel

This is a free-flow tunnel, 12·4 km. in length, designed for a discharge of 16 cu. m. per sec. Over a length of 9·0 km., with a gradient of 2·6 per cent., it has a cross-section of 9·3 sq. m. in the unlined, and 7 sq. m. in the lined sections. Then follows a 3·4 km. section, with a gradient of 1·3 per cent., in which a cross-section of 9·3 sq. m. at the upper end widens out up to 23·6 sq. m. at the surge tank, forming a storage chamber with a capacity of about 35,000 cu. m., which acts as a balancer when both power stations are coupled in tandem, and can also ensure the running of the Moyopampa plant at peak load for short periods.

The geology of the strata encountered by this tunnel offers no complications, and the rock in situ is mostly sound diorite; there is some fissuring in the section from 0 to 1·7 km., and at 2 km. the tunnel runs into a short, slightly mineralised zone. Rock pressure was felt at a few spots, particularly in the widened lower section, but did not delay tunnelling to any considerable extent. Water infiltration was very small, and fans managed to maintain the temperature in the workings at between 24 and 26°C. For hydraulic reasons, the invert is made of concrete throughout, but walls and roof are lined only in friable stretches and at spots where rock pressure occurs; the concreted sections comprise together about 23 per cent. of the

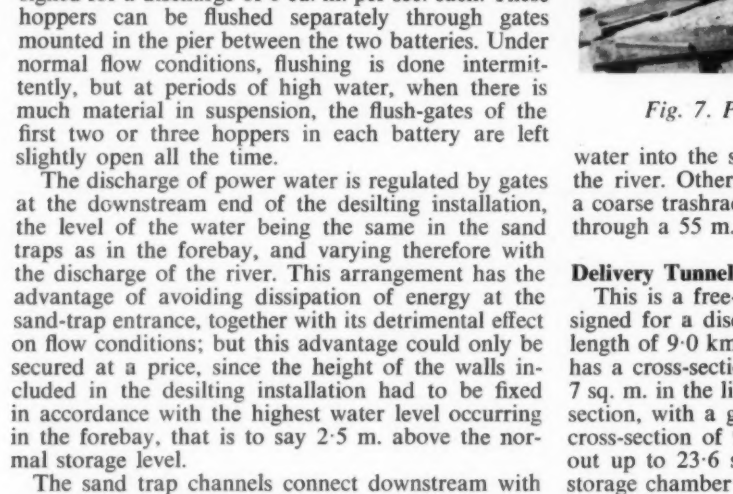


Fig. 6. Penstocks in course of erection at lowest anchor block

total length, half of it with wall and roof lining, and the other half with wall lining only. Inspection is made quickly and easily by using a jeep which is lowered by a crane to the entrance, and moves smoothly on the concrete floor.

Surge Chamber

Broken stone dropping from the unlined sections of the tunnel is trapped in three hoppers, similar to those of the sand traps, located in a small cavity at the lower end of the storage chamber. In the case of stoppages at the power station, spillways at either side of the surge chamber return the excess water to the river through a natural channel running on the left-hand side of the penstocks. A fine screen is fitted in front of the inlet to the penstocks. In the valve chamber adjacent to the surge chamber there are three standard butterfly valves which close the corresponding penstock automatically when the rated discharge is exceeded by about 20 per cent. These valves can also be operated from the power station by electric trips. In front of each valve there is also a wooden gate which can be closed by a hand winch when an inspection is to be made. When the penstocks are being filled or drained, the balance of pressure is effected by means of aeration standpipes which reach above the maximum water level in the surge tank.

Penstocks

The penstocks, 1,800 m. in length, lead in a straight line from the surge tank to the power house over a bare slope of solid rock, and are divided into seven sections by anchor blocks and expansion joints. Their slope varies between 66 and 107 per cent., the middle section, 340 m. long, has a uniform gradient, and is divided by anchor blocks into three sub-sections about equal in length; diameters taper off from 1,250 to 1,050 mm., whereas shell thickness increases from 10 to 27 mm. The pipes rest on supports fitted with steel sliding saddles, spaced 6·0 to 9·0 m. All pipes with a shell thickness below 20 mm. are fitted on either side of each support with reinforcing steel rings. The maximum weight as well as the admissible maximum length of pipe sections were dictated by the erection tackle available on site (rope winch), and 9 m. lengths were chosen for the upper six sections, and 6 m. lengths for the bottom section. The usual haulage track is provided parallel to the penstocks, and its driving winch is housed in the valve chamber of the surge tank.

Two-branch manifolds are coupled by sliding flanges to the curved length of the corresponding penstock at the lowest anchorage (Fig. 6); from the hydraulic aspect, their design proved very satisfactory. Slight buckling occurred when temperature and pressure fluctuations caused elongation or longitudinal contraction, but thanks to the curved shape of the branches, additional stresses remained negligible. Moreover, the loose flanges connecting the manifolds to the penstocks help in reducing these additional stresses to a minimum; the manifolds vary between 1,050 and 650 mm. diameter.

Owing to the greater length of the third manifold, to be erected at the completion stage of the installation, it is intended to use a normal expansion joint instead of flanges for its connection to the curved section of the penstock at the lowest fixed point. At its other end, it will be held by a tubular support resting on a concrete bracket which projects from the foundation of the longitudinal wall of the machine room.

The pipes of the penstocks are made of M I quality Siemens-Martin steel plates for the 1,250 mm. diameter, and of M II quality for the other diameters and the manifolds, which have a thicker shell. All seams are electrically welded, and after welding, all pipes with a shell over 20 mm. thick, as well as the whole set of manifolds, were submitted to stress-relieving annealing at 620° C. Shell thicknesses were calculated on the basis of the static pressure increased, as usual, by 10 per cent., in consideration of the water-hammer pressures occurring in actual service; admissible circumferential stresses of 10·0 to 11·5 kg. per sq. mm. were also taken into account, and, to the thicknesses thus obtained, an extra 1 mm. on straight sections, and 2 mm. on fittings was added for corrosion.

All pipes were delivered with a double coat of "Inertol" laid after sandblasting, and all imperfections found in the coating after erection were thoroughly corrected, whereupon the whole conduit was coated again with "Inertol," a single coat being applied to the interior, and a double one on the outside. Before laying the final outer coat, an aluminium pigment was aded to the paint to protect against the intense solar irradiation.

Power House

Two sites were taken into consideration for the construction of the power house, one between the toe of the slope and the motor road (Carretera Central) leading from Lima into the country, and the other, somewhat farther down, between the road and the river: the former site was selected after calculation

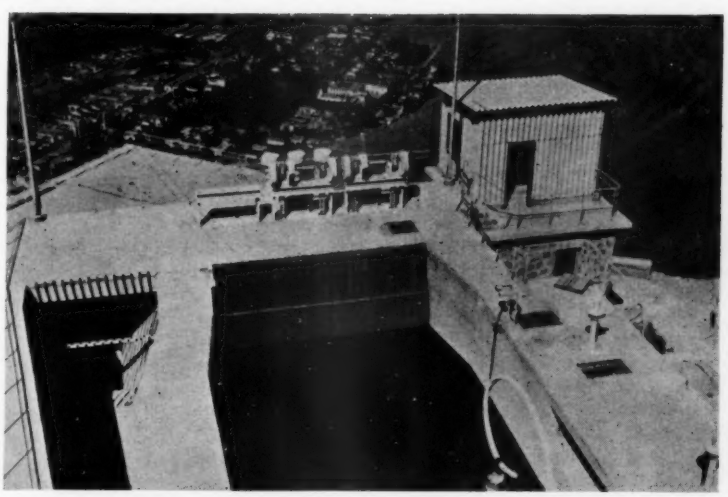


Fig. 8. Surge tank with overflow weir in background

had proved that the few metres of head gained by shifting the power house closer to the river would not balance the expenditure involved in the extension of the penstocks.

The generating station consists of three adjacent buildings, the machine hall, the service accommodation, and the switching and transformer station. The superstructure is a reinforced-concrete framework with brick filling, and the flat concrete roofs of the three buildings are separated from each other by expansion joints. Additional horizontal and vertical stresses were taken into account in the calculation of all the superstructures, since earthquakes are not exactly a rare occurrence in the Moyopampa district.

Ancillary Works

The tailrace canal consists of a 70 m. covered upper section connecting with an open lower section of the same length; at the junction of the two sections, an overflow weir is provided for test measurements. The waste channel running from the surge tank down the slope extends, at the point where it reaches the trough of the valley, into a masonry channel, 250 m. long, leading to the river. This channel has a length of 750 m., with a gradient varying between 60 and 100 per cent., which is reduced to 5 per cent. in the masonry section. Other ancillary works are an emergency channel which leads from the back of the power house to the masonry section of the waste channel, and a track for the transport of heavy machinery from the railway on the left bank of the Rimac into the power station.

Fig. 9. General view of Moyopampa power station, showing penstocks and waste channel

Construction Procedure

Construction of the project was entrusted to the Motor-Columbus A.G., who concluded a joint agreement with the well-known firm of Danish contractors Christiani & Nielsen. The whole of the construction equipment was bought by the Hidrandina and placed at the disposal of the contractors, together with all the necessary building materials.

Work began with the laying of access roads 11 km. in aggregate length and the erection of service transmission lines, 5 km. long, to the site of the surge chamber and to the various access adits of the tunnel, as well as with the building of accommodation for about 1,500 workmen. The main camp was set up at the approximate centre of the various building sites, to which the men were conveyed by lorries. It lies just outside the lower limit of the breeding ground of the gnat which transmits the dreaded "verruga" disease, and, indeed, a few dwelling huts had to be erected inside that zone, near the Lucmaseca adit and the water intake, two spots which are at too great a distance from the main camp. Thanks to an extensive use of D.D.T., verruga, which had claimed so many victims at other building sites in Peru, did not break out at Moyopampa.

The intake works were built in three stages, first the left half of the weir, then its right half, work on the latter overlapping in part of the construction of the sand traps.

The delivery tunnel was driven from four access adits on seven faces, and the tunnelling equipment available included jumbos, wet-drilling hammers and power shovels, together with ventilation fans, electric locomotives and other implements. The longest distance between two adits measured 3·8 km. The supply of water for wet drilling was a difficult proposition, since water had to be either pumped from the valley through several kilometres of pipeline or

brought by lorries. The whole length of the 9·3 sq. m. section was driven to full cross section, and so was the section of the storage chamber 12 to 16 sq. m. in cross section. In the lower 16 to 23·6 sq. m. section of this chamber, a pilot gallery was first excavated and then widened by blasting. Aggregate for the concrete lining of the tunnel was mostly obtained from the spoil.

Surge chamber and penstocks rest on sound rock, and building operations on these two items of the scheme met with no difficulty worth mentioning.

The subsoil at the site of the power house is a compact deposit of aluvium, and the underground water table lies several metres below the lowest foundation level. The foundation work went smoothly.

Work on the machine hall proper, which of all the station buildings has the longest span of roof and the greatest height between floor and crown, began with the concreting of the columns of the longitudinal walls together with the tracks of the 35 ton travelling cranes, after which the cross girders of these cranes were lifted into position to carry the scaffolding supporting the shuttering of the roof. By means of this improvised travelling erection structure, the concreting of the roof was effected in five stages, and much timber and labour was saved. All concrete was vibrated.

Before putting the plant into service, the waste channel from the surge tank to the Rio Rimac was thoroughly cleared of weathered debris and of the spoil excavated in connection with the erection of the penstocks. Sluicing had to be repeated fifteen times to clear the channel adequately, and no less than 15,000 cu. m. of material was flushed away.

Work proceeded everywhere at a very creditable rate, and, to mention two sections of the scheme only, the delivery tunnel was completed in 39 months and the power station with its ancillary works in 36 months.

(To be continued)

Correspondence

The Salanfe Project

To the Editor of WATER POWER

The Salanfe penstock installed in Switzerland has the following particulars:—

Static pressure	...1,474 m.
Total length	...4,634 m.
Diameter	1·300 to 1·100 m.
Maximum wall thickness ...	51 mm.
Total weight	...3,130 metric tons

The Salanfe penstock is constructed of ordinary welded pipes, without hoops, in a semi-hard steel made of a special alloy. The factor of safety under the working pressure (static pressure plus surge pressure) is required to be about 2 with respect to the elastic limit, but the hydraulic test pressure is less than twice this working pressure.

My company's technique would enable us to build this penstock in the following manner. Over a length of 1,350 m. the lower portion of the penstock would be constructed of overpressured, heat-treated, and self hooped pipes. The pipe walls would be in steel having a minimum elastic limit of 34 kg. per sq. cm. and would be overpressured to 3 per cent., and the jointless hoops would be in heat-treated steel having a minimum elastic limit of 70 kg. per sq. cm. and overpressured to 2 per cent. After the overpressuring process the pipe would be subjected to a thermal treatment to 250°C. All the upper part of the penstock would consist of welded pipes constructed in the same steel having a minimum elastic limit of 34 kg. per sq. cm., overpressured to 4 per cent., and heat treated to 250°C. after the overpressuring process.

The weight of such a penstock would be much less than that of the one installed: 1,960 instead of 3,130 metric tons under markedly improved conditions of safety. The factor of safety with respect to the elastic limit would, in fact, be 2·4, and the test pressure would be at least twice the working pressure.

Our technique thus enables us to achieve a saving of 40 per cent. on the weight of material employed. It presupposes the use of special steels of high elastic limit; but any manufacturer wishing to obtain such economies would be obliged to use high-quality steels for this penstock. Nevertheless it should be emphasised that it would not be possible to obtain such savings in materials without reducing the factor of safety to its extreme limit. The use of overpressured and self-hooped overpressured pipes enables this difficulty to be avoided, even though the factor of safety is 2·4 and the works hydraulic test is taken to double the working pressure.

The saving in cost is most important, for even if the somewhat higher price per ton of our overpressured and self-hooped pipes as compared with welded pipes prevents the reduction in cost of the penstock itself from being in the same proportion as the reduction in weight, this factor will be largely compensated by the ease of transport and, above all, of erection. In considering erection and particularly welding it should be noted that the plate thicknesses employed for our overpressured pipes and particularly of our self-hooped pipes are very much less than those of welded pipes constructed in similar steel (actually about one-fifth).

G. FERRAND,
President Director General,
Société Dauphinoise d'Etudes et de Montages,
Grenoble.

Single Jet Pelton Turbines

To the Editor of WATER POWER

May we be allowed to draw attention to a statement on page 384 of the October issue of WATER POWER, which contains an informative and very interesting article under the heading "The Salanfe Development." The statement in question reads as follows:—

"A remarkable feature of the three horizontal-shaft Pelton turbines, developing each 47,500 h.p. at 500 r.p.m. is that this great power is obtained by means of single jets; these turbines, indeed, are claimed to be the most powerful machines of this type built to the present day."

It occurs to us that your contributor could not have been aware of the two Single Jet Single Runner Turbines designed and built by Riva for the Avise Power Plant, Italy. Each of these special turbines is rated at 62,000 h.p.

Brief particulars relating to the Riva Impulse Turbines for the Avise Power Plant were given in our advertisement in the September 1953 issue of WATER POWER.

S. L. R. HOLLIS,
Managing Director, Ferrum (England) Limited.

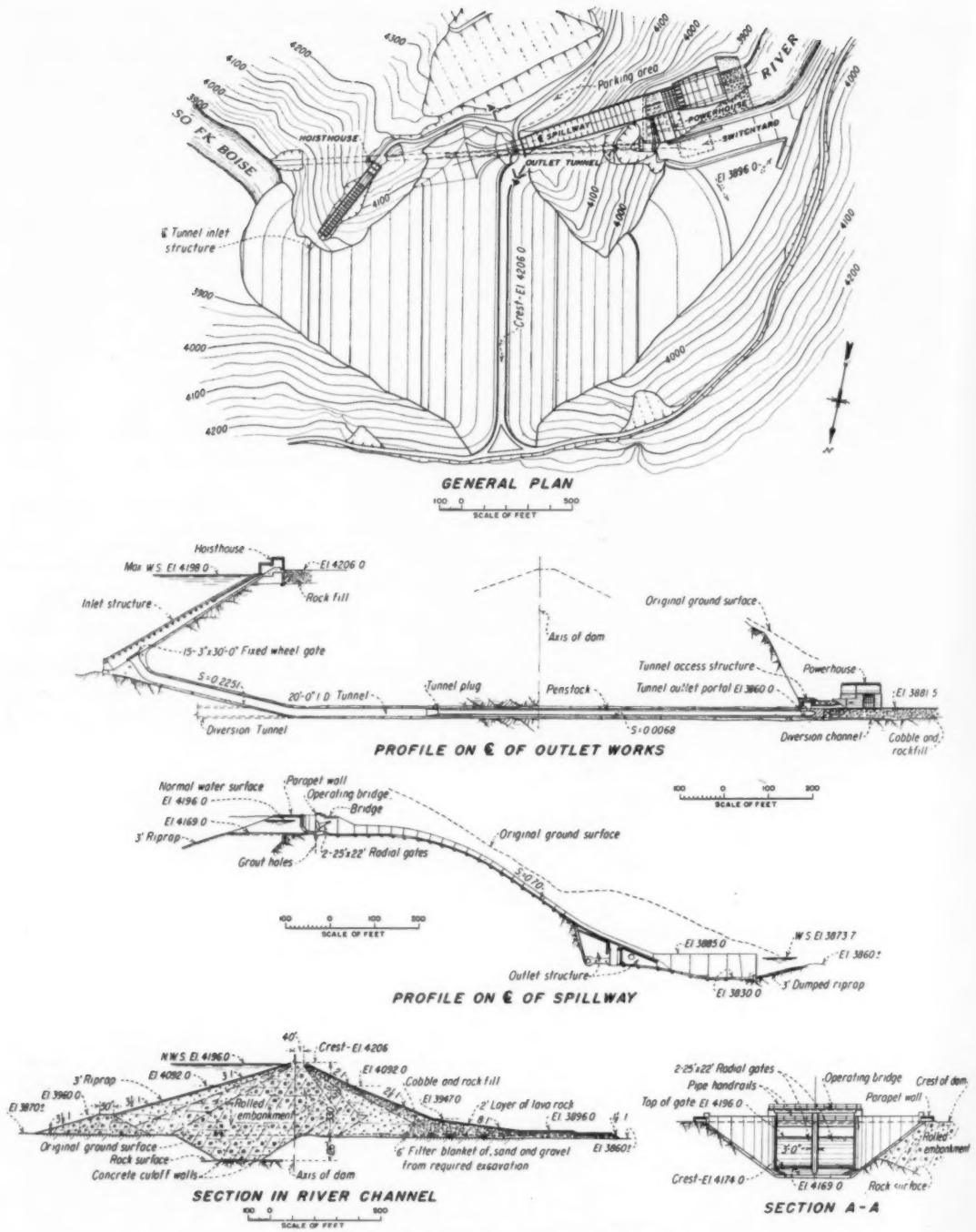


Fig. 1. Plan and profiles of Anderson Ranch dam

Fig. 2. View of Anderson Ranch dam from upstream

Anderson Ranch Dam and Power Plant

By D. L. GOODMAN, Engineer, Bureau of Reclamation,
Denver, Colorado.

This article describes the design and construction of Anderson Ranch dam and power plant and their appurtenant works. The dam and power plant are major features of the Bureau of Reclamation's Boise project in the State of Idaho in the northwestern United States.

ANDERSON RANCH dam is the highest earthfill dam in the world, rising 456 ft. above the lowest point of its foundation. Construction of the 9,653,300 cu. yard dam embankment was completed in October 1947. The first of the power plant's present two 13,500 kW generators was placed in operation in December 1950; the second unit began operation in July 1951.

Boise Project

As early as 1864, settlers in the Boise river basin, recognising the potential value of irrigating the fertile basin lands, began development of a system of simple ditches which diverted water directly from the streams. By 1900, about 148,000 acres of land had been placed under irrigation. Development of additional lands, too difficult and costly to be undertaken by private capital, was begun in 1906 by Federal Reclamation in response to petitions signed by the local irrigators.

The 350,000 acre Boise project, as developed by the Bureau of Reclamation, extends into Ada, Canyon, Gem, and Payette Counties in Idaho, and into a small area in Malheur County in Oregon. The project area, having an average elevation of 2,500 ft. above sea level, has a semi-arid climate which requires the application of irrigation water from April until October of each year for an average irrigation

season of six months. Water is supplied for the project from the Boise and Payette Rivers and from certain springs and drains within the project.

Five major dams and reservoirs, two principal diversion dams, three sizable pumping plants, and three power plants have been built on the project. The irrigation works provide water both to lands receiving their full water supply from the project and to lands which are supplied supplemental water.

The Boise project consists of two divisions—the Arrowrock and the Payette. Although some of the project features function for one division only, other features serve both, as well as other nearby Bureau of Reclamation projects.

The Arrowrock division embraces 269,000 acres of irrigable lands. Storage for this division is provided in Anderson Ranch reservoir, Arrowrock reservoir on the Boise River, and Lake Lowell, an off-stream reservoir. Anderson Ranch dam is 42 miles upstream from Arrowrock dam. Sixteen miles downstream from Arrowrock dam and 7 miles south-east of the city of Boise, Idaho, stands Boise diversion dam, which during the non-irrigation season diverts a part of the water released from Anderson Ranch and Arrowrock dam into a 45 mile canal to fill Lake Lowell. Power is produced at Boise diversion dam, as well as at Anderson Ranch dam.

Lands in the 85,000-acre Payette division receive water from the Payette River and surplus drainage from the Arrowrock division. The storage features comprise Deadwood reservoir on Deadwood River, a tributary of the South Fork of the Payette River, and Cascade reservoir on the North Fork of the Payette River. Water is diverted into the distribution system at Black Canyon diversion dam, downstream on the main Payette River. An 8,000 kW power plant has been built at Black Canyon dam.

The multiple-purpose Boise project embraces one of the most productive farming areas in the world. It is one of the leading dairy regions in the United States, as well as a major seed-producing area. Eighty per cent. of the entire country's requirements for hybrid sweet corn and about 60 per cent. of the nation's sweet corn seed supply are grown on the Boise project and the Bureau's nearby Owyhee project—the result of ideal growing conditions, fertile soil, and dependable water supply. The project also produces large quantities of sugar beets, alfalfa, and other crops, and its hay and forage support a vast number of sheep and cattle which range in nearby hills and mountains.

The project's power plants serve irrigation pumping loads. Surplus power from the project's three-plant power pool is sold to preferential customers, such as co-operatives; the remainder is made available to private power companies.

Purpose and History of Dam Construction

Anderson Ranch dam was constructed for the initial purpose of providing supplemental storage to prevent serious shortages of irrigation water on the Boise project lands lying principally between the Boise and Snake Rivers. The primary purpose of the Anderson Ranch reservoir, however, is to serve as a source or irrigation water for the proposed 400,000 acre Mountain Home project east of the Boise project, also in Idaho. In addition to serving irrigated lands, Anderson Ranch dam provides flood control benefits to the Boise valley and its power plant adds to the power potential of the area, serving pumping loads in the nearby Minidoka and Owyhee projects, as well as contributing to the project's power pool. (More than 141 million kWh of electrical energy were produced at the plant in 1952.) Silt retention is also a project benefit provided by Anderson Ranch reservoir.

Construction of Anderson Ranch dam was authorised by the Secretary of the Interior on August 12, 1940, under the provisions of the Reclamation Project Act of 1939. Appropriation of funds for start of construction of the dam was approved by the Congress of the United States on June 28, 1941. Bids for construction of the dam were opened in July 1941, and the contract was awarded to Morrison-Knudsen Company, Incorporated, J. F. Shea Company, Incorporated, Fred J. Twaits Company, and Winston Brothers Company on their joint low bid. Construction, under the contract, began on August 7, 1941.

Labour and material shortages during the war years, 1941 to 1946, greatly retarded the progress of construction. In December 1942, the War Production Board issued an order to cease all activity at the dam site, except that considered necessary to protect the work completed. In October 1943, the Board modified its order, as a part of the War Food Programme, to permit the completion of the dam and reservoir (without power facilities or spillway gates), thus assuring that supplemental water would be provided for irrigated lands in the Boise River valley. This work subsequently allowed the storage and release of 80,000 acre-feet of water to the valley in 1946, and 130,000 acre-feet in 1947, thus materially aiding the production of foodstuffs in the Boise area.

All War Production Board restrictions were removed in October 1945, allowing construction of the dam, power plant, and appurtenant works to proceed. The Morrison-Shea-Twaits-Winston contract was terminated on March 31, 1948, following completion of the dam embankment in October 1947. In April 1948, completion of construction of the dam appurtenant features and power plant, including the spillway and outlet works, and switchyard structure, was begun under a separate contract awarded to J. A. Terteling and Sons, Incorporated, of Boise, Idaho. Work under this contract was completed in October 1950.

Preliminary Investigations

Anderson Ranch dam is located in a relatively narrow, rugged canyon of the South Fork of the Boise River. Initial geological studies undertaken prior to construction of the dam indicated that the rock throughout the mountainous areas of the Boise River drainage basin consisted principally of coarse-grained granite through which numerous dikes of harder basic rocks had intruded. The granite is persistently jointed, fractured, and locally crushed, and, as a result, generally disintegrates rapidly under the influence of weathering elements. The ancient river in the vicinity of the dam site apparently excavated a wide valley having a floor about 400 ft. above the present stream bed. This valley was subsequently filled with basaltic lava to depth of about 600 ft. The river then carved a narrow canyon through this material and into the granite to a depth of about 120 ft. below the present stream bed. A later outpouring of lava downstream

Fig. 3. View of Anderson Ranch dam, power plant and related features taken after completion

from the dam site resulted in the formation of a deep, narrow lake into which the rivers and streams deposited their debris as deltas. Eventually, the river cut through the lava flow barrier, and as the lake was lowered, extensive erosion of the delta deposits occurred. Subsequently, a considerable thickness of recent river silts, gravels, cobbles, and boulders was deposited over the earlier delta-deposited silts, sands, and gravels.

For the foundation of the dam, the principal investigations included the location and competency of the bedrock on which the dam and appurtenant structures would be founded, the depth and quantity of the overburden to be removed in obtaining acceptable foundations for all structures, and the extent and suitability of the overburden for use in the embankment. The investigations revealed—through use of diamond drill and churn drill holes, test pits, and test drifts—that the bedrock was composed of igneous rock. This rock was mainly friable granite which could be used as a foundation for the dam, provided that adequate provisions for sealing the numerous joints and fractures were incorporated into the design.

Laboratory tests on samples of materials obtained at the dam site indicated that a large amount of the overburden to be excavated could be used as acceptable embankment material. To supplement the materials obtained from an estimated 2,000,000 cu. yards of required excavation, suitable embankment material was required to be located in borrow areas near the dam site. Initial search for materials centred in the delta and outwash deposits along the river. These investigations showed such deposits to consist entirely of pervious or semi-pervious materials useful for the outer zones only. Investigations were then shifted to an area on the lava bench high on the right abutment. When the quality of the impervious material in this area proved unsatisfactory, the investigations were transferred to an area high on the left abutment about 2 miles downstream from the dam site; here a sufficient quantity of satisfactory impervious material was found to be available. This area, designated as the Dixie borrow area, consisted of an alluvium outwash derived from the granite uplands. It varied in depth up to 125 ft., covered about 500 acres and contained an estimated 10,000,000 cu. yards of earth material for the impervious centre zone of the dam. Investigations for a satisfactory source of rock for the upstream riprap and facing over the downstream rock fill revealed that a durable basalt rock was obtainable from a talus deposit of lava rock in Elk Creek Canyon, located about half a mile upstream above the dam site and from other sources. Material for the rock fill section of the dam embankment was obtained from the excavation for the spillway and outlet works and from other excavation in the left abutment of the dam.

Reservoir

When filled to capacity at high water elevation, 4,196 ft. above sea level, the Anderson Ranch reservoir contains 500,000 acre-feet of water. Of this total capacity, about 464,000 acre-feet is active storage. Allocations of the reservoir are: flood control,

212,500 acre-feet; irrigation, 212,500 acre-feet; power, 45,000 acre-feet; and silt retention, 30,000 acre-feet.

The reservoir has a surface area of 4,740 acres and is about 13 miles in length. A county road extending up the river valley, and several roads constructed by the Forest Service, were inundated by the reservoir. More than 30 miles of gravel surfaced roads were accordingly constructed to provide access to the ranches, timber lands, and other areas above the reservoir. Much of this road relocation was difficult construction along the steep side slopes forming the reservoir. About 5,000 acres of land in the reservoir area were cleared of timber and brush; merchantable timber was salvaged, and the remaining trees and brush were stacked and burned. The small village of Pine, Idaho, in the upper reservoir area, was purchased and all usable property was salvaged before storage of water began. Three bridges across the river in the reservoir area were salvaged and used on the relocated road.

Design and Construction of the Dam

The design of Anderson Ranch dam and construction of the earth embankment to its unprecedented height presented many problems for both the designers and the builders. The depth of overburden in the stream channel, the relatively weak and broken bedrock, and the absence of nearby sources of large quantities of suitable aggregates for concrete were important factors which influenced the decision to construct the embankment of earth and rock materials. To complete the construction of the dam the contractors excavated about 11,300,000 cu. yards of earth and rock materials for the 9,653,300 cu. yard embankment. This is roughly equivalent to excavating 700 acres to a depth of 10 feet. In raising the earthfill portion of the embankment from bedrock foundation to crest elevation, the material for more than 900 layers of embankment was transported to the dam, carefuly processed to obtain homogeneity of material and uniformity of moisture content, levelled to predetermined thickness, and compacted by tamping rollers.

In addition to the ordinary laboratory tests performed to determine the physical properties of embankment materials, special testing was necessary to establish placement control procedures which would assure a stable structure. The variety of earth materials available permitted the design of a zoned embankment, which was particularly desirable for this high structure. The problem of building a stable structure while at the same time utilising the available materials from the most economical locations was frequently analysed as additional information on borrow areas became known. The zoning of the dam was accordingly modified several times during the period from the preliminary design phase to completion of construction.

The 40 ft. wide crest of the dam embankment is about 330 ft. above the stream bed and 456 ft. above the lowest point in the cut-off trench. The dam's crest length is 1,400 ft. and the base width is about 3,000 ft. in the original river channel section. The central portion of the embankment is constructed of impervious material and functions as the water barrier. A pervious zone downstream drains the seepage through the impervious core, and between this pervious zone and the core a transition zone of semi-pervious material is provided to preclude any possibility of removal of the fine core material by the percolating water. A zone of rockfill extending downstream to the toe of the dam provides additional safety against failure of the downstream slope. A 6 ft. filter blanket of sand and gravel was placed beneath the downstream pervious and rockfill zones and prevents possible loss of fine material from the foundation through these zones. Upstream from the central core a semi-pervious transition zone and a pervious zone assure stability to the upstream slope during reservoir drawdown and prevent removal of fines from the impervious zone by wave action through the 3 ft. blanket of protective riprap.

A cut-off trench, 200 ft. wide at the maximum section, extends through the river-bottom materials and the abutment overburden to bedrock. Two concrete cut-off walls, having a maximum height of 16 ft. and with footings extending 3 ft. or more into bedrock, are located in the cut-off trench across the bottom of the canyon and up the abutments. These walls serve to prevent seepage along the contact of the cut-off trench backfill and the bedrock. Cement grout pumped under pressure through vertical holes placed at 10 ft. centres formed curtains under each of the concrete cut-off walls. The grout curtains extend as much as 150 ft. into the foundation rock, and together with blanket grouting through holes 30 ft. deep placed at 20 ft. centres between the two walls, they assure against excessive seepage beneath the dam.

The upsteam slope of the embankment is protected

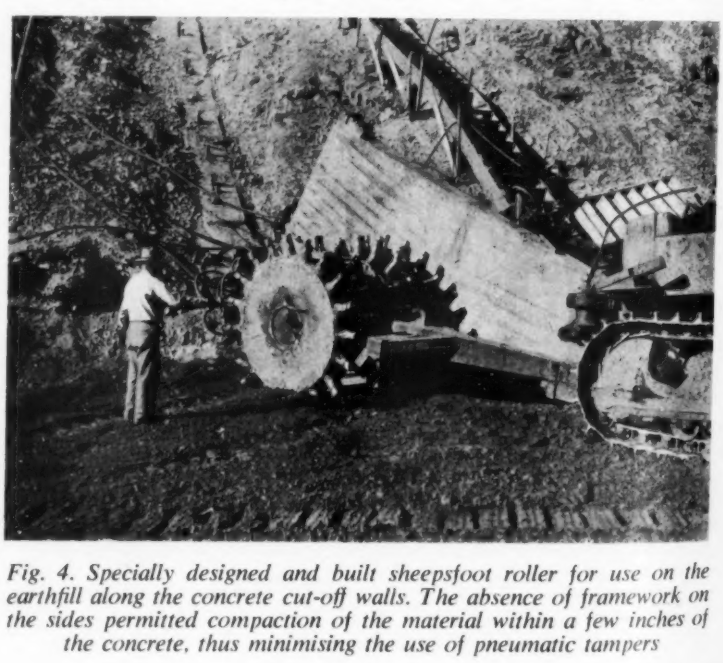


Fig. 4. Specially designed and built sheepsfoot roller for use on the earthfill along the concrete cut-off walls. The absence of framework on the sides permitted compaction of the material within a few inches of the concrete, thus minimising the use of pneumatic tampers

Fig. 5. View up the left abutment showing the final flight of the two-mile conveyor system which transported borrow material to the dam site

from wave attrition by a 3 ft. layer of hard, durable, lava rock riprap. A 2 ft. layer of similar rock placed on the face of the downstream rockfill zone protects the friable granite in this zone from erosional and weathering damage and gives a uniform appearance to the slope.

An effective means of diverting the river from its channel through the embankment area was provided by driving the outlet tunnel through the left abutment. Working from both portals on a three-shift basis, the contractor excavated the tunnel in 80 days. Construction operations were so planned that concreting of the lining could be started while excavation of the tunnel was progressing. Virtually all materials from the tunnel excavation were placed directly in appropriate zones of the embankment.

As soon as the diversion tunnel had been concrete lined, excavation of the overburden from the abutments was started. Initial cuts were made with bulldozers which pushed the material over the steep slopes. Stripping, consisting of top soil, vegetation or other organic material, was wasted. The remainder of the material was placed in the cofferdam or stockpiled for later use in the main embankment. The initial diversion of the river was successfully carried out despite the high flows prevalent in the river at that time; excavation of the river bottom material was begun immediately after.

The contractor anticipated that large quantities of water seeping into the cut-off trench would be the most difficult problem to overcome during construction of the cut-off trench, cut-off wall foundation, foundation grouting, and during backfilling. To control such seepage the contractor dug two vertical shafts, one upstream and one downstream from the axis near the left abutment, to depths well into the rock well below the elevation of the bottom of the cut-off trench. Drift tunnels were also constructed, reaching across the valley to a point near the right abutment. Several plans of draining the foundation water into the tunnels were tried, the most successful being a series of 3 in. diameter perforated pipe extending through the overburden into the roofs of the tunnels. A cave-in of a portion of the upstream tunnel filled it with sand and rendered this system inoperative. Pumps were maintained at each shaft, however, and a small amount of water was removed by this system.

The greater portion of the seeping water was pumped from sumps in the bottom of the trench as the excavation progressed. Wellpoints installed on the trench slopes, and which were extended downward as the excavation progressed, removed additional water and prevented sloughing of the steep sloping sides of the trench. In general, the anticipated difficulties from seeping water did not materialise—about 2,700 gallons per minute was the maximum seepage.

Material from the cut-off trench was classified as it was excavated and it was directed to appropriate sections of the dam embankment, to stock piles, or to waste piles. About 630,000 cu. yards of material were removed in 110 days of round-the-clock operation.

The two concrete cut-off walls were constructed across the river bottom and partially up the abutments as soon as possible after the foundation had been excavated to bedrock. Drilling and grouting the cut-off curtains through the pipes placed in the cut-off wall footings followed immediately. Some of these grout holes, drilled with pneumatic diamond drills, extended as much as 150 ft. into bedrock.

Backfilling of the trench began after the grouting and cut-off walls were completed. The material for the central Zone 1 portion of the dam embankment, of which the cut-off trench is a part, was obtained from the Dixie borrow area, located on a high flat about 2 miles downstream from the left abutment and 1,200 ft. above the river bottom. Because of the difficulty of constructing haul roads to this area, the

contractor installed a conveyor system to transport the earth material to the embankment.

The conveyor system consisted of six flights of 36 in. wide belt extending from the borrow area to the left abutment. The material was excavated by two 5 cu. yard shovels and was dumped into a hopper at the end of a "pendulum" belt feeder. From this feeder belt, the material was transferred to the first of the six flights of the main conveyor belt. The 2 mile-long system of belts moved the material at a speed of 550 ft. per min., a little more than 6 miles an hour, and had a maximum capacity of 900 cu. yards per hour. Discharged from the end of the conveyor system over the left abutment, the material was allowed to roll down the steep slope to the embankment level. The most practical method of adding moisture to the embankment material, when such moisture was necessary to ensure the desired placement condition, was the use of jets spraying the soil as it was dumped from the conveyor belt.

Because of the unusual height of the dam embankment, extensive laboratory studies were undertaken to determine moisture and density relationships which would permit economical placement, yet ensure stability. Relatively narrow limits of moisture and density were established for the impervious material as a result of these studies and each lift was processed and carefully controlled to within these limits.

Materials for the semi-pervious and pervious zones of the dam were obtained mainly from the Whipple borrow area (a delta deposit upstream from the dam), from the slide area excavation on the left abutment, from required foundation excavation, and a small amount from the Dixie borrow area. Approximately 2,200,000 cu. yards of these materials were processed through a separation plant. The plant had an operating capacity of 900 cu. yards per hour and produced three types of materials—rockfill, pervious, and semi-pervious materials.

The impervious and semi-pervious zones were placed in 8 in. loose layers, moistened additionally if necessary to meet the pre-established limits, and rolled 12 passes with ballasted tamping rollers. The rollers had two 5 ft. sections and weighed 20 tons. Lifts that became smooth from truck travel, or that dried out, were scarified and moistened before a new lift was placed. All rocks over 5 in. in maximum dimension were removed from the fill before rolling was allowed. Along the cut-off walls, at abutment contacts, and in other areas inaccessible to the large rollers, compaction was obtained by use of pneumatic hand tampers and by a narrow-drum frameless roller constructed at the dam site.

In the bottom of the cut-off trench and up the abutments in the area beneath the impervious zone, the bedrock was carefully cleaned by hand and with air and water jets before the embankment material was placed. The foundation area under the rockfill zone was levelled and rolled before the filter blanket, consisting of free-draining coarsely graded sand and gravel, was placed. This filter blanket material was placed in 12 in. layers and compacted by travel of construction equipment.

The pervious-zone material was placed in 12 in. layers and compacted by sluicing and travel of the construction equipment. The rockfill was placed in 3 ft. layers and covered on the outer slope with a 2 ft. layer of lava rock. Riprap rock, consisting of well-graded durable lava rock ranging in size from half a cubic foot to half a cubic yard and larger, was placed on the upstream slope, the riprap placement keeping pace with the embankment placement. Some hand work was necessary to obtain uniform distribution of the larger riprap rock and to "dress up" the slope.

To maintain control of the placement moisture and density values within acceptable limits, Bureau engineers carried out more than 3,000 field density tests on material for the compacted zones of the dam. A test pit excavated through a portion of the constructed embankment showed that satisfactory placement of the materials had been achieved.

To determine the behaviour of the completed dam embankment, piezometers and cross arms were embedded in the dam as construction progressed. Thirty-one piezometers were installed to record the pore pressures within the soil mass. The piezometer tips were connected by plastic tubing filled with water to gauges located in a terminal well at the downstream toe of the dam. The tips and tubing were installed in small trenches dug across the embankment during construction. Pressures which develop in the embankment are transmitted through porous discs to the water column and are recorded on the terminal well gauges.

The cross arms installed in the embankment permitted measurement of the settlement of the foundation under the dam and consolidation within the embankment itself as it was constructed and after construction was completed. The cross-arm arrangement consists of a series of alternating pipe sections, $1\frac{1}{2}$ and 2 in. in diameter, the smaller pipe telescoping inside the larger pipe. The $1\frac{1}{2}$ in. pipe sections are anchored to the embankment by means of 3 ft. long cross arms bolted and welded to the pipe. Any movement of the dam embankment is thus communicated to the cross arms. Settlement is measured by lowering an engaging device down the pipe system. The device may be engaged at the bottom of each $1\frac{1}{2}$ in. pipe section, permitting measurement of the position of each cross arm. Two such installations were made in the dam, one having 74 cross arms above the centre of the cut-off trench and the other having 59 cross arms located downstream from the cut-off trench excavation.

Spillway

The spillway at Anderson Ranch dam is a concrete-lined open channel cut through a prominence of the left canyon wall and down the aubutment to the river channel. It has a maximum discharge capacity of 20,000 cu. feet per second. The spillway channel chute is unusually steep, having a maximum slope of 0·70. The channel width flares from 53 ft. near the top to 100 ft. at the stilling basin in order to spread the sheet of water as it cascades down the incline into the stilling basin. The lower portion of the channel chute extends over, and is supported by, the outlet works control structure. Dentated sills are placed at the end of the stilling basin to dissipate further the destructive energy of the discharging water. A drainage system of sewer pipe drains, embedded in gravel, is installed under the spillway floor and behind the walls downstream from the gate structure.

Because of the fractured and soft broken rock of the spillway channel area, steel anchor bars, $1\frac{1}{4}$ in.

square, varying in length from 4 to 15 ft. and spaced at 7 ft. centres, were embedded to tie the spillway floor to the foundation. Anchor bars of 5 and 10 ft. lengths were also embedded in the spillway stilling basin. The similar condition of broken, shattered rock at the spillway gate structure location dictated the construction of heavy, counterforted walls in this section, in lieu of lighter walls placed directly against the rock.

Two 25 by 22 ft. high radial gates were installed at the crest of the spillway to regulate the flow of water discharged over the crest. Flow is maintained equally under both gates at all times. The radial gates consist of a face plate which is a sector of a circle, connected by arms to pivots at the centre of curvature. The gates are constructed of structural steel and are raised by means of a double drum hoist on the hoist bridge over the spillway; double hoisting cables from each hoist drum are attached to both ends of the bottom of the gate leaf. The gates close by their own weight when the hoisting cables are unwound from the hoist drums.

The two hoist drums are driven by a single electric-motor-operated reduction unit located on the hoist bridge midway between the two hoist drums. Push-button control stations located on the bridge adjacent to the hoist motors are provided for manual control of the gates. In addition, the electric hoist drive of each gate has a float control that opens and closes the gate to maintain maximum storage in the reservoir and at the same time provide protection against damage to the dam by a sudden reservoir rise. A float-operated high-water alarm is also provided to sound a danger signal when maximum high water level in the reservoir is reached.

An ice-prevention air system consisting of two electric-motor-driven air compressors, a distribution piping system, and appropriately located discharge nozzles, is installed in the spillway structure to prevent ice pressure against the spillway radial gates. Compressed air is discharged through the nozzles below the surface of the water in front of the radial gates. The air bubbles developed by the discharging air lift the comparatively warmer water at the lower depth to the surface in the manner of an airlift pump. The warmer water reaching the surface thus provides an ice-free area in front of the radial gates. Air for the discharge nozzles is supplied by either of two air compressors located in a compressor house at one side of the spillway. One air compressor supplies the required volume of air, and the other compressor serves as a standby unit.

Outlet Works

The outlet works at Anderson Ranch dam consist of an inlet structure with trashrack; a 20 ft. diameter, concrete-lined outlet tunnel, about 1,700 ft. long; a 15 ft. diameter, plate-steel penstock header, 832 ft. long, extending from a concrete plug in the tunnel to the power house and to the outlet structure under

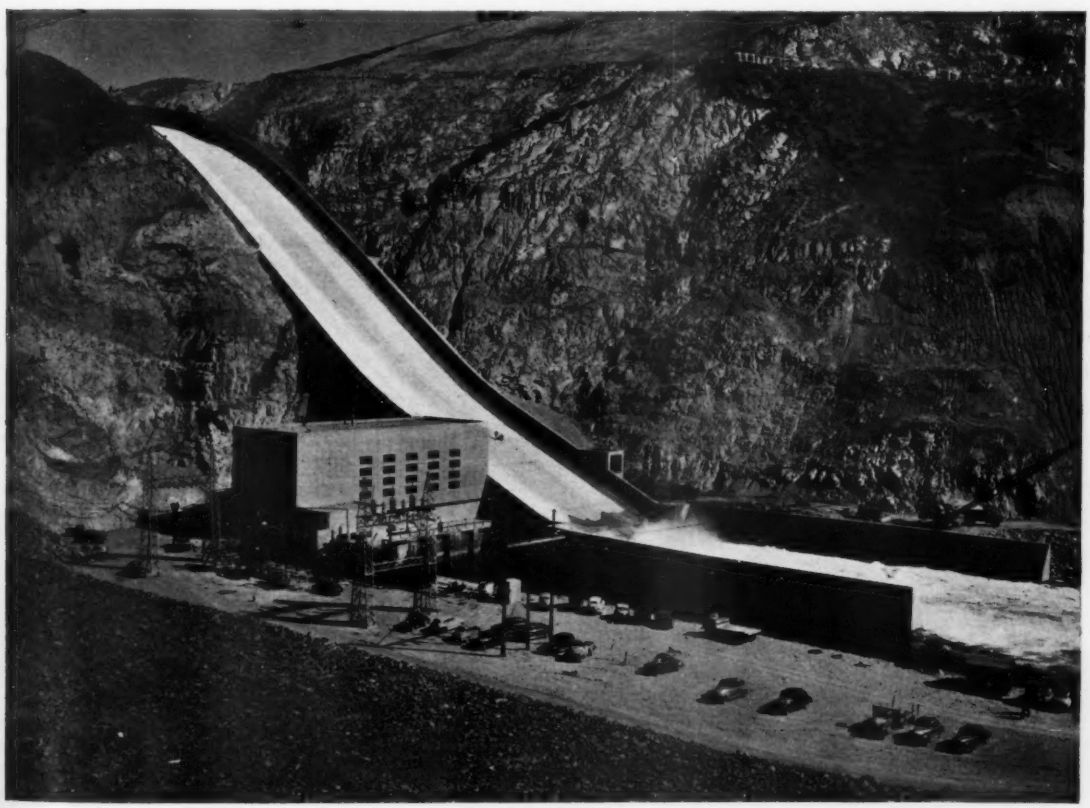


Fig. 6. Anderson Ranch power plant and spillway

the spillway channel to serve the dual purpose of delivering water to three hydraulic turbines in the power plant and of releasing water for irrigation through five outlet pipes; and five 72 in. hollow jet valves which regulate flow of the outlet pipes. Each of these features is described in this sequence in the following discussion.

The original design plans called for the inlet structure from the reservoir to the outlet tunnel to be built about 80 ft. directly above the line of the tunnel; the inlet was to lie on a 1 : 1 slope and be connected by an inclined shaft intersecting the tunnel 170 ft. from the inlet portal. However, because of the steep slope and resulting landslides, it was considered inadvisable to continue with the original design. The final design required the present inclined inlet structure to lie on a $1\frac{1}{2}$: 1 slope and to be moved to a position on a granite ridge about 200 ft. to the north (or right) of the tunnel line. The inlet, as constructed, connects the outlet tunnel by an inclined tunnel sloping at an angle of about 30° with the horizontal and intersecting the main tunnel at a point 350 ft. from the inlet portal.

The inlet structure is a long, narrow concrete chamber, 43 ft. wide and about 400 ft. long. It is about 30 ft. deep at its lower end and about 8 ft. deep at its juncture with the wall of the gate-hoist house at the top of the inlet. The chamber is covered by metal trashrack bars which in turn are supported by reinforced-concrete beams and girders.

A 15 ft. 3 in. by 30 ft. bulkhead-type fixed-wheel gate is installed in the inlet structure to control flow from the reservoir to the outlet tunnel and for closure purposes when the penstock is required to be temporarily taken out of service for maintenance, repairs, or inspection. The gate is a flat-leaf steel structure having 10 fixed wheels on each side of the leaf to carry the gate load on rails. The gate operates in an inclined slot, lateral movement of the gate being limited by means of two guide rollers on each side of the leaf which bear against guide plates on each side of the slot. The gate is raised and lowered by means of an oil-pressure-operated hydraulic hoist mounted at the top of the gate slot in the hoist house and is connected to the gate by removable gate stem sections, $6\frac{3}{4}$ in. in diameter and totalling about 368 ft. in length. Each gate stem section is supported at the upper end by a carriage having wheels that operate on rails near the centre of the gate slot.

The fixed-wheel gate weighs about 257,000 lb. and is held in the open position by means of a yoke at the upper end of the gate slot. The gate is opened and closed under balanced head conditions only, but it may be closed in an emergency under full flow.

The 20 ft. inside-diameter 1,700 ft.-long outlet tunnel is located at the south side of the dam. It is lined with concrete, average thickness of the lining being about 2 ft. for the full tunnel length. In order to divert the river flow through the inclined outlet tunnel it was necessary not only to close the upstream end of the diversion tunnel but also to seal effectively the partially excavated inclined shaft which had been originally intended to serve as the permanent intake. Since the inclined shaft was full of loose material, it was sealed by placing an 8 ft. thick concrete plug at the top of the concrete lining in the lower part of the shaft.

Closing of the upstream end of the diversion tunnel was done by means of a heavy timber bulkhead that was supported against the upstream end of the tunnel lining and which was reinforced by three steel beams set in recesses that were formed in the tunnel lining when the concrete was placed. The lower portion of the timber bulkhead consisted of a hinged flap gate which was held in open position by steel cables until final closure was made on December 15, 1945.

Following closure of the upstream end of the diversion tunnel, a concrete plug was placed in the tunnel. The plug is 95 ft. long, extending upstream from the intersection of the inclined inlet with the diversion tunnel, and ending 278 ft. downstream from the inlet portal. Another concrete plug, 100 ft. long, beginning 793 ft. downstream from the inlet portal, closes the annular area between the 20 ft.-diameter tunnel and the 15 ft.-diameter penstock header.

The penstock header is a straight plate-steel pipe extending 832 ft. from the concrete plug in the outlet tunnel to a 15 ft.-diameter 90° bend which in turn leads to a penstock and outlet manifold. The manifold is located partly under the spillway structure, is about 190 ft. long, and varies in diameter from 15 ft. at the upstream end to 6 ft. at the downstream end. Three 90 in. penstocks branch off the upstream portion of the manifold and lead into the power plant. Two of these penstocks are waterways for the two existing generating units; the third is bulkheaded pending installation of the third generating unit. The manifold is reduced in size beyond the third penstock intake to supply five 72 in. plate-steel outlet pipes.

Support rings bearing on concrete piers located on both sides of the penstock header support the header from the tunnel plug to the tunnel portal. The penstock manifold and the penstocks and outlet pipes beyond the tunnel portal are all embedded in concrete.

The penstock pipe system was designed for a static head of 326 ft. plus a water-hammer head of 94 ft., or a total head of 420 ft. Plate thickness in the 15 ft. header varies from 1 in. to $1\frac{3}{8}$ in. in the shell between supports and from $1\frac{1}{2}$ in. to $1\frac{5}{8}$ in. over the supports. Plate thicknesses in the manifold, penstock, and outlet branches are $\frac{5}{8}$ in. for the 72 in. pipe, $\frac{3}{4}$ in. for the 90 in. pipe, and vary from $1\frac{1}{8}$ in. to $1\frac{3}{8}$ in. for the manifold header. The plates in the branch outlets vary from 1 in. to $1\frac{5}{8}$ in. in thickness.

In January 1950 a hydrostatic pressure test was performed on the entire penstock and outlet pipe system. During this test, a 50 ft.-long longitudinal crack occurred in the 15 ft. header. The fracture ran across three pipe sections. Subsequently, the fractured plates were removed and new plates were installed. In August 1950 the penstock system was then tested again at a maximum test pressure of 275 lb. per sq. in. The pressure was held for three hours without any leakage or sign of overstress in any part of the penstock system. Soon after the test was completed, the penstock and outlet pipe system was placed in operation and has since performed satisfactorily.

A 100 in. butterfly valve is installed in each generating unit penstock about 6 ft. upstream from the turbine scrollcase to serve as a shut-off valve. Each valve consists of a body and a leaf bulkhead. Rotating the leaf within the valve body from a position parallel to one across the water flow, closes the valve. The leaf rotates on a horizontal shaft through an angle of 90°, the bottom of the leaf moving in the direction of water flow when opening.

A 72 in. hollow jet valve is installed on the end

Fig. 7. Interior of power station showing Nos. 1 and 2 13,500 kW generators

of, and used to regulate the discharge of water from, each of the outlet pipes. The valves are attached to the flanges of the outlet pipes which extend beyond the embedded portions into the valve chambers. The valve chambers are provided with stoplog grooves on the stilling-basin end so that with the installation of stoplogs, one valve may be taken out of service while the remaining outlets may be discharging. Each valve has its individual control unit which is located directly above the valve on the operating floor and which consists of a motor-driven reduction unit driving the valve-operating shaft.

The hollow jet valve consists of a body and a needle. The needle can be moved along the centre line of the body by a screwjack operated by an electric-motor-driven control unit. When the needle is moved to the upstream end of the valve it seats and closes the valve. As the valve is opened water flows past the periphery of the needle in the shape of a cylindrical ring along the inside of the valve body.

The five outlet valves have a combined discharge of 10,000 cusecs, and each valve is designed to regulate the discharge of water through the outlet pipe from zero to a maximum of 2,500 cusecs.

A 72 in. ring-follower gate is installed in each of the outlet pipes ahead of and used as an emergency and guard gate for the hollow-jet regulating valve. These gates are hydraulically actuated and are designed to be normally opened and closed under balanced head conditions, although emergency closure under full flow can be made. Each gate consists of a body with upper and lower bonnets and covers containing a leaf bulkhead having a ring follower. The leaf bulkhead stops the water flow when placed across the outlet pipe openings in the gate body and the ring follower provides a smooth water passage when it is placed in the same position.

The outlet structure consists of six vertical longitudinal walls which are supported laterally by struts and cross-walls. The longitudinal walls form five chambers through which water is discharged from the outlet valves into the spillway stilling basin immediately downstream. The four intermediate walls support the section of the spillway passing over this area. An overhead crane, located in the valve chamber immediately above the ring follower gates and hollow jet valves, is used to remove or install valves as required for maintenance.

Power Plant

Anderson Ranch power plant is located on the right side of the outlet works and is a 101 by 139 ft. reinforced-concrete structure. Roof girders and purlins are of structural steel. The plant at present houses two 13,500 kW main generating units and station service equipment. However, space is available for a third generating unit of the same capacity for installation at a later date. Thus, the present capacity of the power plant is 27,000 kW and the ultimate capacity will be 40,500 kW.

Each of the installed generators is rated at 15,000 kVA, 90 per cent. power factor, 3 phase, 60 cycles, 6,900 V, 277 r.p.m. They are of the vertical-shaft type having a thrust and upper guide bearing above the rotor and a lower guide bearing. The entire weight of the rotating parts of each generator and turbine is supported by the thrust bearing, which in turn is supported by the upper bearing bracket which also supports the main and pilot exciter and the permanent-magnet generator. This entire load is transmitted successively through this bracket to the stator frame, thence to the soleplates and on into the foundation. The lower bracket supports the lower guide bearing and air brakes.

Each generator is excited by a direct-connected vertical-shaft shunt-wound 100 kW 250 V separately excited main exciter mounted on top of the generator, which in turn is excited by a direct-connected compound-wound 4 kW 250 V self-excited pilot exciter mounted on top of the main exciter. The permanent-

magnet generator is direct connected to the pilot exciter shaft and is mounted on top of the pilot exciter. Generator voltage is controlled either manually or by an automatic voltage regulator which adjusts the field current of the main exciter by means of a motor-operated main-exciter field rheostat. A manual control and a separate direct-current regulator control the voltage of the pilot exciter.

Each generator is equipped with an enclosed cooling system, complete with air ducts, heat exchanger located on the upstream side of the generator, metal housing, and blades attached to the rotor to act as a blower to circulate the air. The generator housings are practically airtight and permit the use of automatic CO_2 fire-extinguishing equipment.

Each generator is equipped with air-operated brakes of sufficient capacity to bring the rotating parts of the generator and turbine to a stop from one-half normal operating speed within five minutes after the brakes are applied without field excitation on the generator. The brakes are also designed for use as hydraulic jacks to lift the generator and turbine rotating parts a sufficient distance to provide for removal or adjustment of the thrust bearings.

The power transformer installation consists of two banks of single-phase transformers connected delta on the low-voltage side and solidly earthed star on the high-voltage side, with space provided for a third bank. Each power transformer is single-phase 60 cycle oil-immersed self-cooled outdoor-type, rated at 5,500 kVA 6,600 V to 66,400/115,000 Y-volts. External radiators provide adequate cooling to the transformers under normal conditions. The transformers are suitable for service at rated voltage and capacity at an elevation of 3,900 ft. above sea level.

The turbines for Anderson Ranch power plant were designed and supplied by the James Leffel and Company, Springfield, Ohio. At present, the turbine installation for the power plant consists of two vertical-shaft Francis 277 r.p.m. hydraulic turbines, each having a capacity of 18,500 h.p. at full gate opening, when operating under a net effective head of 245 ft., corresponding to full generator rating of 15,000 kVA at 90 per cent. power factor. At heads above 245 ft., the turbine output is limited to the generator capacity by operating at restricted turbine gate openings. The point of best efficiency is about 260 ft. net effective head, when the turbine output is approximately 17,000 h.p. Warranted best efficiency of the turbine is 90·2 per cent.

Gross operating head on the turbines varies between 174 ft. and 329 ft.; average head is about 260 ft. The estimated head loss from forebay to each turbine is approximately 5 ft. at rated discharge.

Hydraulic capacity of the turbines is determined from the most efficient use of water available and stored in the reservoir. The discharge and plant factor upon which the turbine installation is based is 2,990 acre-feet per day, or 1,510 cusecs, and a plant factor of about 50 per cent.

The turbine spiral case and other parts subject to water pressure are designed to withstand a hydrostatic pressure of 180 lb. per sq. in., which is the maximum operating pressure, including water-hammer. The spiral case was shop tested at 250 lb. per sq. in. and tested in the field before being embedded in concrete. Hydrostatic pressure of 140 lb. per sq. in., corresponding to maximum effective operating head of 324 ft., was maintained within the case while the concrete surrounding it was being placed. The spiral case is made of cast steel, in four sections with bolted flanges, and with the stayring cast integral with the spiral-case sections.

Each turbine is designed and constructed so that all removable parts, including runner, shaft, guide-bearing support, top and bottom covers, gate-operating mechanism, and the wicket gates, may be removed from above by means of the main power-house crane, and so that all parts can pass through the circular pit below the generator and through the generator stator. The turbine shaft and runner can be raised or lowered as a unit, for purposes of checking or inspecting the generator thrust bearing, or disconnecting the main shaft coupling.

The turbine runner is made of cast steel in one piece, and is so designed and constructed that it will safely withstand the stresses resulting from operation at runaway speed at maximum head, including pressure rise, when the turbine wicket gates are wide open and when there is no load on the generator except windage and friction. The runner will support its own weight and the weight of the turbine shaft when the latter is disconnected from the generator shaft and the runner is resting on the ledge in the discharge ring. Provisions were made in the design of the runner crown and band for the future installation of wearing seal rings.

The turbine shaft is made of forged open-hearth carbon steel, and is designed to operate at any speed up to runaway speed without vibration or objectionable distortion. A 4 in. diameter hole is bored axially throughout its entire length.

Twenty movable wicket gates control the supply of water to each turbine runner, the number of gates and the number of stay vanes being co-ordinated to such a manner as to ensure that the turbine will run without objectionable vibration. Each turbine has two oil-pressure double-acting hydraulic servomotors having a combined capacity sufficient to supply the maximum required force to move the wicket gates a full-opening or full-closing stroke in five seconds.

Means are provided to unwater each of the turbine units for inspection and overhaul purposes. With the wicket gates and the penstock butterfly valve closed, a plug valve adjacent to the butterfly valve can be opened to unwater the spiral case. After the bulkhead gates are lowered into position, a drain valve, located in the draught-tube pier and operated from the downsteam pipe gallery, can be opened to unwater the draught tube.

Major mechanical handling equipment in the power house includes a 60 ton capacity travelling crane and a 45 ton capacity transformer transfer car. The crane is a motor-operated, overhead travelling crane operating on a runway extending the length of the power house above the generator and assembly floor. It is used for installing and servicing the main power-plant equipment and untanking the power transformers. The transformers are moved on the transfer car, movement of the transfer car being on rails normal to the transformer deck rails and the rails entering the power-house doorway.

Switchyard

The switchyard at Anderson Ranch dam has three bays, one for accommodating the output from each

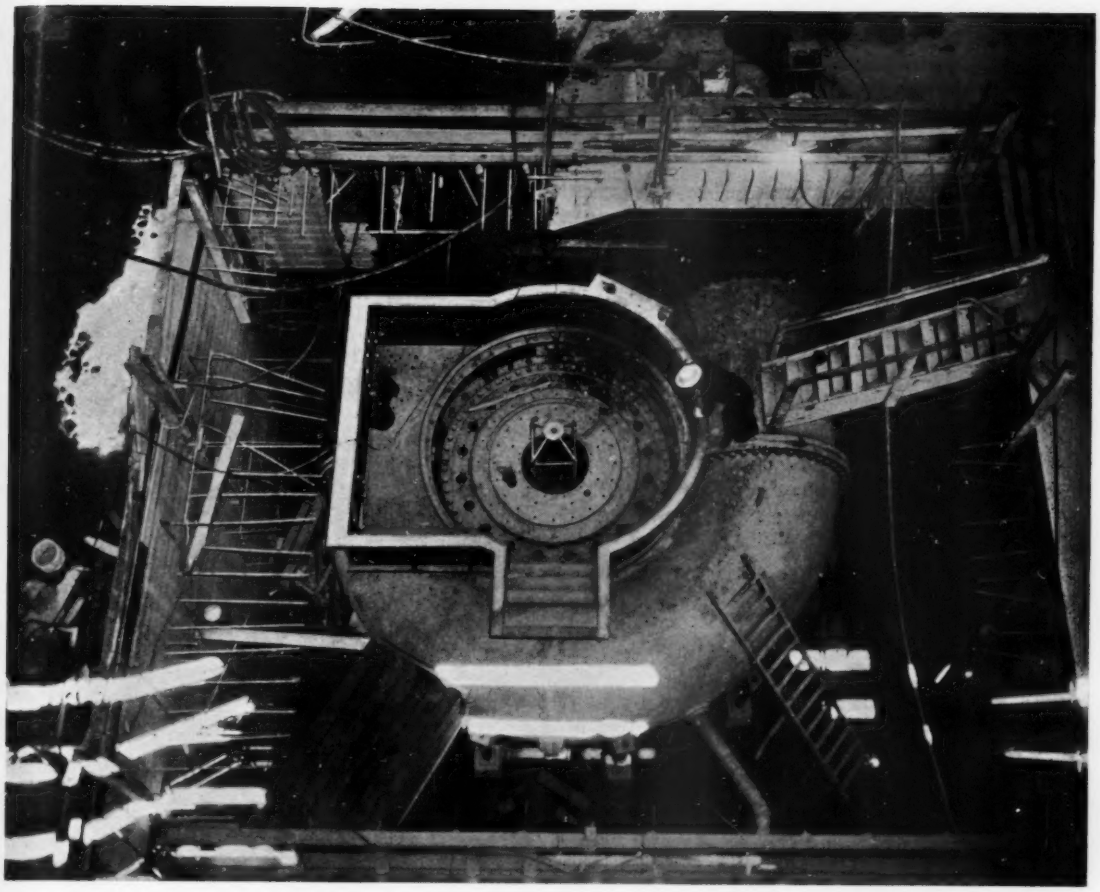


Fig. 8. View of the spiral case and pit liner for one of the 18,500 h.p. Leffel turbines taken during construction

of the two generators, and the third bay for the future installation of another generating unit. Switching equipment for the two bays now in service at the Anderson Ranch switchyard consists of the following: two 115 kV 800 A 3-pole outdoor-type oil circuit breakers, having a rupturing capacity of 1,500,000 kVA, and rupturing time of 5 cycles, and a possible reclosing time of 20 cycles; two 115 kV 600 A 3-pole single-throw vertically-mounted manually-gang-operated outdoor-type disconnecting switches, one for isolation of each oil circuit breaker from the common switchyard bus; one 115 kV 600 A 3-pole single-throw manually-gang-operated outdoor-type disconnecting switch having arcing horns installed about 40 ft. above the ground on the line take-off structure; and three 115 kV coupling capacitors with potential devices, used to obtain potential for synchronising, relaying, and for carrier-current telephone service.

The 115 kV oil circuit breakers are electrically controlled but are closed by means of pneumatically operated mechanisms. Each operating mechanism is pneumatically trip-free, and with its control equipment, is electrically trip-free and non-pumping when closed on short circuits.

The switchyard installation is now being modified to provide service to the Prairie Power Co-operative in Idaho. This service will be available through low-voltage switchgear in the plant and a 2,000 kVA three-phase transformer having an output voltage of 24·9 kV. The new installation will be in accordance with recent practice to distribute power to rural areas over an earthed-star circuit at this voltage.

Personnel

The Anderson Ranch dam and power plant design and construction was under the direction of Mr. S. O. Harper, the Bureau of Reclamation's Chief Engineer from 1940 to 1945. Mr. Walker R. Young was Chief Engineer from 1945 to 1948. Mr. L. N. McClellan is the Bureau's present Chief Engineer; his offices are in Denver, Colorado. Mr. John A. Beemer was the Bureau's Construction Engineer in charge at the dam until his retirement in 1944. He was succeeded in turn by Construction Engineers H. F. Bahmeier, Donald S. Walter, and G. A. Swanson. The dam is located in the Bureau's Region 1, of which Mr. R. J. Newell was Regional Director until his retirement in 1949. Mr. Harold T. Nelson is the present Regional Director.

"Marelli," Vol. 27, No. 1-2, January-February 1953, published by the Ercole Marelli concern in Milan. This issue contains, among other articles, a description of the S. Matteo power station, entirely reconstructed by this concern after the war.

Minnesota International Hydraulics Convention

This Convention, which combined the fifth plenary meeting of the International Association for Hydraulic Research and the second separate meeting of the Hydraulics Division of the American Society of Civil Engineers, was held at the University of Minnesota in September. We summarise some of the papers having relevance to hydro-electric practice.

PART ONE

THE Minnesota International Hydraulics Convention, which combined the fifth plenary meeting of the International Association for Hydraulic Research and the second separate meeting of the Hydraulics Division of the American Society of Civil Engineers, was attended by scientists and engineers from 18 countries throughout the world, as well as delegates from 35 states of the United States and the District of Columbia. Preceding the Convention by one day, there was also in session a Hydrology Meeting of the North Central Regional Branch of the American Geophysical Union.

At the opening session, Dr. Theodore C. Blegen, Dean of the Graduate School of the University of Minnesota, made the welcoming address and stressed the importance of freedom of thinking and international co-operation in all research work, whether fundamental or applied. Dr. E. C. Stakman, the world-renowned plant pathologist, addressed this session on a topic phrased "Land and Water—May They Get Together Better." The speaker at the concluding luncheon meeting of the Convention was Major-General S. D. Sturgis, Jr., Chief of Engineers of the U.S. Army, who discussed "Water Resource Development."

During the course of the Convention a half-day tour was made through the St. Anthony Falls Hydraulic Laboratory, displayed in full operation.

The International Association for Hydraulic Research selected Delft, Netherlands, for its next plenary meeting to be held in September, 1955.

The theme of the Congress was directed toward four geophysical aspects of hydraulics as follows: Basic Relationships of Sediment Transportation by Flowing Water; Density Currents; Air Entrainment by Flowing Water; and Waves, Beach Erosion, and the Hydromechanics of Shore Structures. No less than 49 papers were presented by 75 authors from some 20 countries. A welcome feature of the Convention was the prepublication of all these papers in a volume, illustrated by about 550 diagrams, charts and photographs, containing some 570 $8\frac{1}{2} \times 11$ in. size pages.* The preprinting of the Technical Proceedings proved to be exceptionally effective in co-ordinating the technical sessions and stimulating discussion.

It is our purpose in this article to summarise those papers which deal with problems having some fairly direct relevance to the hydro-electric field. Owing to the large number of papers presented and the stringent limitations on our space our treatment will unavoidably be uneven, and readers desiring greater detail are referred to the published Proceedings. Nevertheless we trust that this summary will serve a useful purpose in providing a brief conspectus of the Convention from the hydro-electric angle.

Basic Relationship of Sediment Transportation by Flowing Water

Fourteen papers were presented in this section. A particularly interesting contribution of immediate importance to the hydro-electric domain is "Dredge Fill Closure of Missouri River at Fort Randall," by Lorenz G. Straub, President of the International Association for Hydraulic Research, Head of the Civil Engineering Department of the University of Minnesota and Director of St. Anthony Falls Hydraulic Laboratory. Dr. Straub's paper describes a unique application of the hydraulic-fill method to the closure

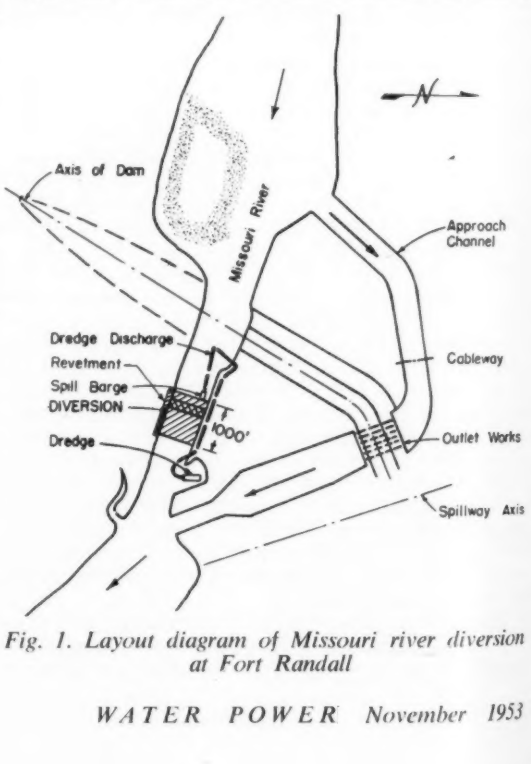


Fig. 1. Layout diagram of Missouri river diversion at Fort Randall

* A limited supply of copies of the Proceedings is available from St. Anthony Falls Hydraulic Laboratory, Minneapolis 14, Minnesota, U.S.A., at $6.00 per copy plus 75 c. postage.

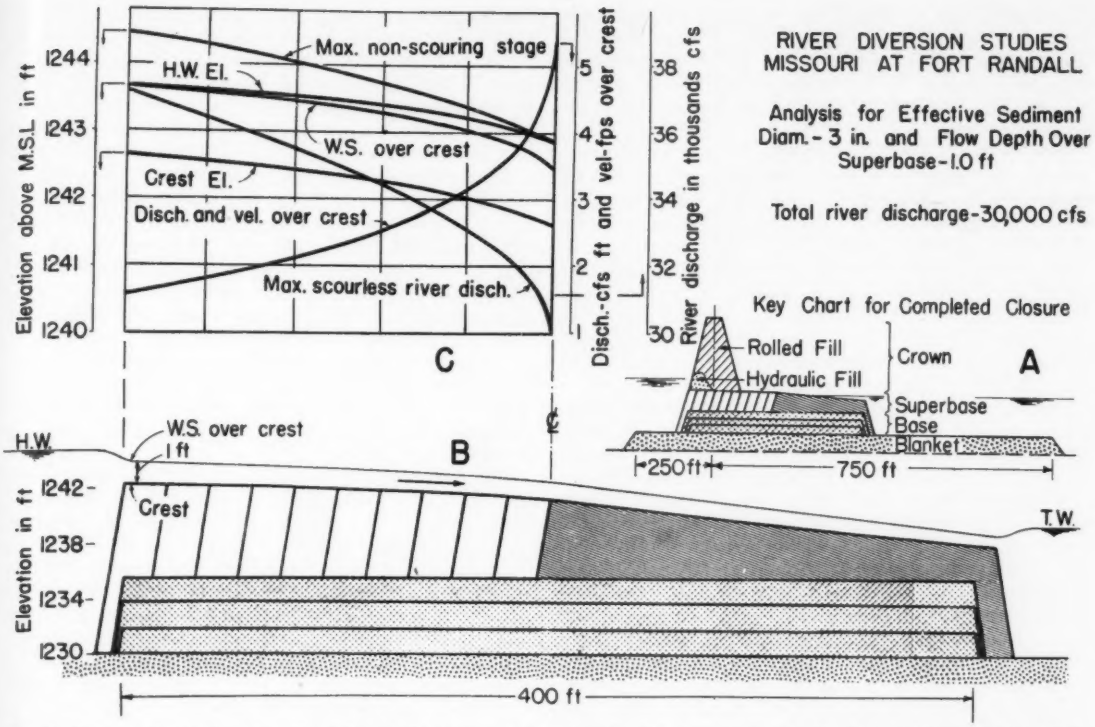


Fig. 2. Schematic design for Fort Randall closure by hydraulic fill for case of effective sediment diameter 3 in. and specific weight 125 lb. per cu. ft. (specific gravity 2·2), for river discharge of 30,000 cfs. (A) schematic cross section of fill and blanket, (B) cross section showing detailed stages of construction, (C) curves for superbase hydraulic characteristics during progress of construction of phase II of the superbase

of a dam as against the customary rockfill closure, the method being based on the concept of "friction control" of the flow as distinguished from "obstruction control" or "critical-depth control" as used in rockfill closure.

Fort Randall dam is of rolled earthfill construction containing 28 million cubic yards of material; it is 160 ft. high above flood plane and will impound 6,200,000 acre feet. A diagrammatic site plan is reproduced in Fig. 1, showing the river diversion, the approach channel and the permanent outlet works, the latter of which had been already constructed. At the diversion point the river channel had been constricted to about 1,000 ft. in breadth. The left bank was initially stable and the right bank had been reveted the previous year by 25 ft. thickness of chalk rock over a length of 1,000 ft. The bed had not been stabilised because it was subject to heavy degrading and aggrading with variations in river flow. In the event the decision to postpone work on the bed proved to be wise because about three months before closure operations were due to begin there occurred the heaviest recorded flood of 460,000 cusecs.

The only convenient fill material readily available in any quantity was chalk rock spoil excavated from the diversion and spillway channels. It was of low specific gravity, averaging only 120 to 125 lb. per cu. ft., and was liable to disintegrate when pumped through a mile-long 30 in. dredge line. Calculations were accordingly based on an average particle size of 3 in.

The hydraulic-fill procedure was based on the principle of bed-sediment transportation. Model studies were conducted and calculations made which were closely confirmed by the results obtained in the actual undertaking.

When fill material is progressively deposited in an embankment across the bed of a river, the crest of the embankment being kept level, the material continues to accumulate in a heap until it rises to a height at which the critical tractive force on the material is exceeded. The fill then begins to move downstream, assuming a trapezoidal section. The friction imposed on the flow by the back of the mound causes a backwater which diverts a proportion of the flow through the permanent outlet works, and as further material is added the mound lengthens until the friction is sufficient to reduce the flow below the critical velocity. It is then possible to complete the closure by depositing a sill rising above water level.

In following this technique care has to be taken to maintain a level crest, for a depression at any point can lead to the formation of a crevasse, but in the actual construction this can be guarded against by laying down sufficient additional length of fill to ensure stability.

For the actual operation a cutter dredge was employed which was believed to be the largest dismountable dredge in the world, its probable capacity in the chalk rock spoil being probably 20,000 cu. yards per day. It had a 36 in. suction and 30 in. discharge line and could pass boulders up to 14 in. in diameter.

The end of the discharge line was carried on a spill barge controlled by shore winches so that it could traverse the width of the river at various speeds ranging from 5 to 50 ft. per min. and could be moved 400 ft. longitudinally without resetting on the land-based heading.

Fig. 2 shows the schematic design for the closure, which was based on a total river discharge of 30,000 cusecs, final sealing off to take place when the flow over the crest fell below 1,500 cusecs. Actually at the start of the construction of the superbase (see Fig. 2) the river discharge was 28,100 cusecs, dropping to 23,800 cusecs on the day of closure.

The first operation, which was carried out at a river flow of 60,000 cusecs, was to lay down a chalk protective blanket on the bed of the river throughout the 1,000 ft. length, this being raised in 2 ft. layers to elevation 1,230, working in an upstream direction. Next, a base, 400 ft. long, was laid on the blanket, also deposited in 2 ft. layers and working upstream, up to an elevation of 1,236, this being the maximum safe level to accept the draught of the barge. Subsequently the barge could only move laterally, and the most critical operation, the construction of the superbase, phase I, was embarked upon. The fill was deposited along the centreline of the base and lengthened itself to a trapezoidal section until stability was reached. This operation occupied three days. When the downstream portion of the superbase had been completed the barge was moved upstream to complete phase II of the superbase, consisting of strips 25 ft. wide. Actually, due to the reduction of the total river flow, it became unnecessary to complete phase II to the full 200 ft., and closure was effected by a single three-hour sweep across the dyke.

Another paper of considerable interest is "Model Studies of Sediment Control Structures on Diversion Dams," by Harold M. Martin and E. J. Carlson, of the U.S. Bureau of Reclamation. Although the purpose of this investigation was to combat the silting up of irrigation canals its findings are of general application where it is desired to intercept the maximum bed load from an offtake and pass it downstream.

The original study was undertaken in connection with the Superior-Courtland diversion dam (Fig. 3), and a model was built of one half of the weir and the Courtland headworks and sluiceway to an undistorted scale of 1 : 15. To represent the bed load a sand was prepared from a loosely cemented sandstone broken down in a hammer mill, this sand having a median diameter of 0·2 mm. and 90 per cent. between 0·42 and 0·15 mm. The index used to indicate the effectiveness of performance was the concentration of sand in the water passing over the sluiceway to that in the water passing through the headworks, C_s/C_h.

An initial test with the sluiceway and headworks arranged as shown in Fig. 3 but without the guide walls gave a C_s/C_h ratio of 0·682. A system of intermittent sluicing raised this ratio to 0·713 between sluicing periods and to 4·269 during sluicing, but this was abandoned because it was thought that in the actual installation the resulting variation in water level in the canal might damage the banks. Subsequently the various modifications shown in Fig. 4 were tested, and Change No. 4, which gave a ratio of 6·629, was adopted. The use of a vortex tube as shown in Change No. 7 increased the ratio to 7·5, and a subsequent reduction in the sluice width from 20 to 10 ft. further increased the ratio to 10·5. Unfortunately it was not possible to incorporate either of these features in the actual design.

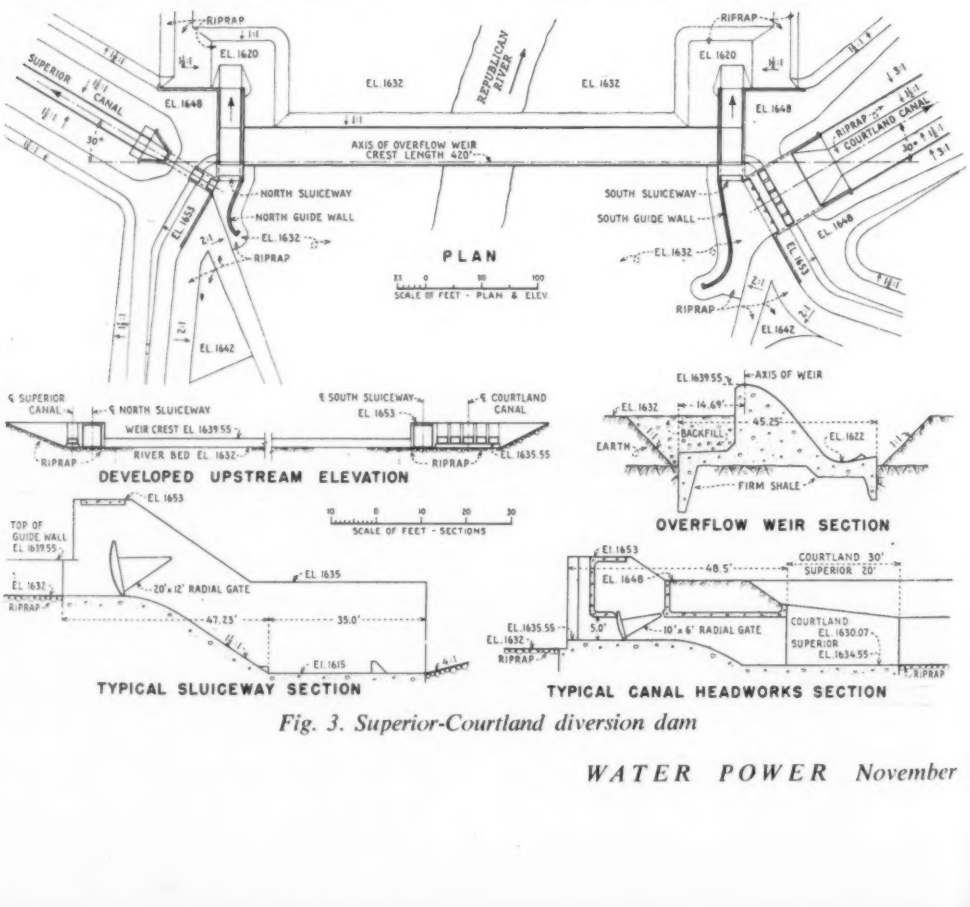


Fig. 3. Superior-Courtland diversion dam

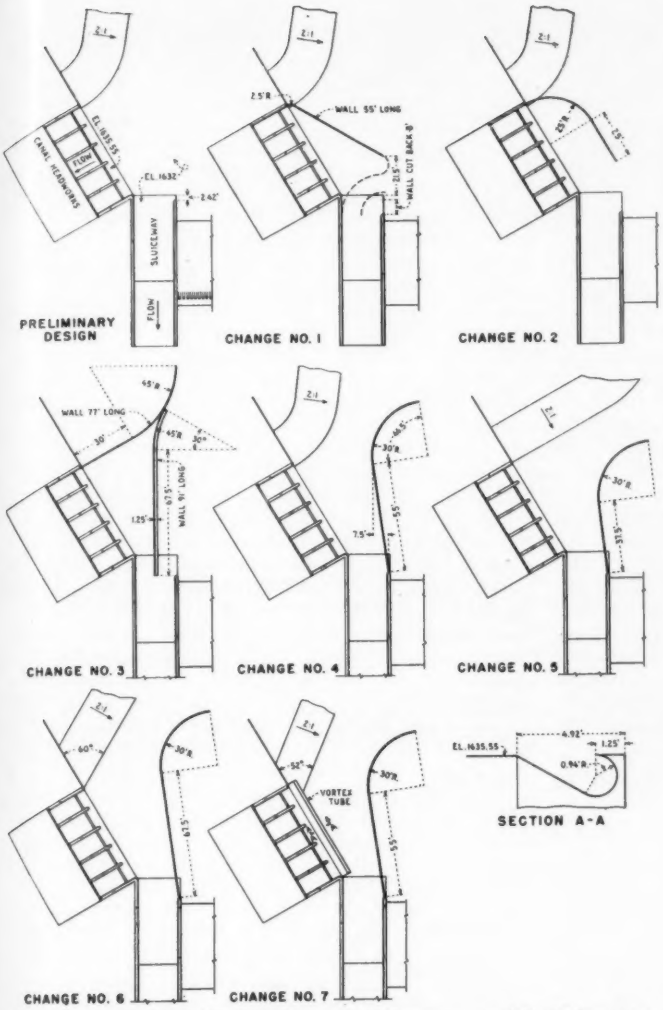


Fig. 4. Courtland headworks and sluiceway model design tests

The model was then modified to test the design for the Superior headworks.

A second study was undertaken on the Republic diversion dam. This was somewhat similar to the Superior-Courtland dam and it was possible to modify the original model. The various designs tested are depicted in Fig. 5, and particular interest attaches to the use of the elliptical vortex tube in Change No. 5. It had been found by other investigators, and was confirmed in these experiments, that an improvement was effected by inclining the vortex tube at an angle to the direction of flow, the angle chosen in this instance being 65°. A further improvement was obtained by placing a horizontal vane over the vortex tube, tapered on the underside upstream and downstream, to increase the velocity above the tube and strengthen the vortex. Three different heights of the vane were tried, as seen in Fig. 5, position 2 at 1 ft. 3 in. being found the best. The vortex tube was first developed by Ralph L. Parshall, but the use of this vane is believed to be original. The best sediment control was obtained with the vortex tube at 65°, the vane at a height of 1 ft. 3 in., and with guide walls, the C_s/C_h ratio being 2·30. An improvement was also effected by installing a sloping floor as in Change No. 6, but the only result recorded relates to a vortex tube at 90° and with no guide walls, the C_s/C_h ratio being 1·84.

The paper also records an investigation on the Bartley dam.

Several papers related to studies of the fundamental relationships of sediment transportation in natural or artificial channels. One of these was "The Motion of Discrete Particles along the Bed of a Turbulent Stream," by Arthur T. Ippen and Ramjee P. Verma, of the Massachusetts Institute of Technology. The primary aim of this study was to reduce the parameters involved in sediment transport in streams to the minimum number which could be accurately controlled and systematically and independently varied. Experiments were made for this purpose in a rectangular channel under the following conditions:

(1) The bottom of the channel was given two types of roughness by coating it uniformly, in each case, with carefully sieved sand.
(2) Four samples of 50 spheres each were used as movable bed load differing in size and specific gravity.
(3) For each roughness the channel slope was varied, and depth and velocity were changed to give uniform flow conditions for a wide range of sediment motion.

The following conclusions were drawn from these studies:

(1) Darcy's friction factor f is preferable to Manning's n in analysing roughness effects in open channels. The pattern of variation with Reynolds number is consistent with the laws accepted for pipe flow on the basis of the Karman-Nikuradse analysis.
(2) The change in relative roughness in open channels is continuous with Reynolds number, and values of f depend always on the absolute roughness k_s. For a given channel, the factor f seems to be governed by a minimum value of k_s/δ', which is reached for low values of the Reynolds number. The line of so-called "smooth surface flow" is not approached for roughened open channels, as is the case for pipes, since the relative roughness $\frac{k_s}{r}$ increases rapidly as the Reynolds number decreases.
(3) An effective hydraulic roughness k_s or equivalent sand roughness must be computed to make the Karman-Prandtl logarithmic functions applicable as usually stated. These values k_s may be appreciably larger than the averages and grain diameter k. This is due to differences of pattern and texture of the surface coating.
(4) A new criterion for incipient particle motion has been given on the basis of rational hydrodynamic concepts. This approach extends the analysis of incipient motion to cases where bed material and

the transported material are different, and thus Shields' function does not apply.

(5) The hydrodynamic effects on rolling particles are such as to produce an average particle velocity, which remains essentially constant in relation to the mean velocity of flow over a wide range of the stream Reynolds number.

In a second paper of this description, "Studies of the Critical Tractive Force of Entrainment of Bed Materials," by Professor L. J. Tison, Université de Gand, Belgium, the author briefly reviews Shields and Manly White's results of the determination of the entrainment force corresponding to the initial motion of solid materials. White has verified that his formula

$$\tau_0 = 0{\cdot}18\ (\gamma_1 - \gamma)\ d\ \tan\ \phi \qquad (1)$$

which is based on theoretical considerations, yields results agreeing with experience in the case of laminar motion. In this formula, γ is the specific weight of the liquid, γ_1 is the specific weight of the materials of diameter d, and ϕ is the natural angle of repose of these materials under water. White has also analysed the case where "large-scale turbulence" does not occur, yet eddies are detached from the tops of the grains ($Re_* > 3{\cdot}5$).

The case of turbulence extending into the general motion has been the object of few verifications, although it is the most frequent. The author is particularly interested in this case. According to Fage, the velocity fluctuations in this case yield instantaneous values that are twice the mean. White concludes that at $Re_* < 3{\cdot}5$, the mean value of τ_0, equal to $\gamma\, hi$ at which entrainment commences, is one-half of Eq. (1), but it is only one-quarter of Eq. (1) at $Re_* > 3{\cdot}5$.

The numerous experiments by the author and those of many other researchers make it possible to calculate τ_0 either from the formula $\gamma\, hi$ or by deduction from $u_* = \sqrt{\tau_0/\rho}$, u in turn being determined with the aid of the Prandtl-Karman law of vertical velocity distribution. Two methods are used, depending on whether or not the velocity distribution has been measured with a Pitot tube along the entire height. In the latter case, the distribution relationship is integrated and u_* is deduced by measuring the mean velocity on the vertical. The authors examine separately the following cases.

(1) The case of $Re_* < 3{\cdot}5$. The values of τ_0 determined by the methods in question show that the magnitudes of τ_0 computed from Eq. (1) should be divided by a factor (which the author calls turbulence coefficient) ranging between 2·46 and 6. The formula proposed for $\tau_0/(\gamma_1 - \gamma)\, d$ at low values of Re_* is not verified, and the quotient $\tau_0/(\gamma_1 - \gamma)\, d$ is taken as ranging between $0{\cdot}18/Re_*$ and 0·03, but not exceeding 0·09.

Moreover, the turbulence coefficient does not depend solely upon Re_*, but also upon other factors and particularly upon the water depth, which is logical.

(2) The case of $Re_* > 3{\cdot}5$. The turbulence coefficient varies between 4 and 7 in accordance with test results in this region. According to White, it must be equal to 4 in this case. The author notes that within the region of $3{\cdot}5 < Re_* < 70$, the tractive forces τ_0 are not yet proportional to the square of the velocity, but comprise one component proportional to the velocity and another component proportional to the square of the velocity. Consequently, to a turbulence coefficient of 4 to 7 (the highest values corresponding to low Re_*) there correspond instantaneous velocity values that are larger than the product of the mean value and the square root of these coefficients.

By noting that at $Re_* < 3{\cdot}5$, the ratio of the instantaneous velocity values to their mean local value yields the turbulence coefficient, ranging from 2·46 to 7; and taking into consideration the preceding statements with regard to $Re_* > 3{\cdot}5$, the author establishes that the differences in the instantaneous velocities with respect to the mean local value, such that they are revealed by the motion of the materials, are relatively greater in the case of low local values than in the case of high local values. The author is of the opinion that this difference actually does not exist, but is due to the high inertia of the coarse grains.

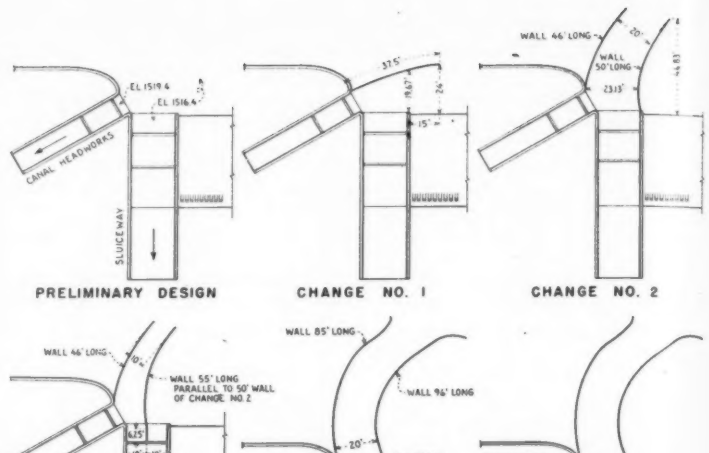


Fig. 5. Republic Diversion Dam, model design tests

A paper, "Variation in Grain-Size Distribution of Bed Load in a River Section," by A. Nizery and G. Braudeau, Electricité de France, comprises a brief discussion of the various major aspects of sediment transportation, an analysis of corresponding formulae as well as their validity and limitations, and a report on the authors' experimental investigation of partial sediment transportation.

The difficulties inherent in establishing universal laws for transportation phenomena are due to the fact that the distribution of the tractive forces in a complex section is unknown, the characteristic diameter involved has not been properly defined, and sediment transportation is either partial or fully developed. There exists a range of tractive forces, corresponding to characteristic water discharges, at which only a fraction of the bed material is in motion; that is, the transportation is partial. This range occurs between the lower critical force of incipient motion and the upper critical force of fully developed transportation at which the sediment in motion is identical to that of the bed material. The Meyer-Peter formula is regarded as valid for the latter condition but is not applicable to partial transportation because it does not take into consideration the corresponding variation in grain size distribution of the transported material at the various water discharges (or tractive forces) in question. Similarly, the formula for partial transportation, developed previously at the Zurich Laboratory, indicates a linear relationship between $Jq^{2/3}$ and $g^{2/3}$ (J is the slope, q and g are respectively the water and solid discharges per unit width of bed) using a characteristic diameter which is inadequately defined in the case of partial transportation.

The authors conducted a series of tests on a 1 : 12·5 model of a river section at discharges ranging from critical flow (incipient sediment motion) to five times critical flow. The model was about 50 m. long, and had a high-stage width of 2·5 to 5·0 m. and an average normal width of 1·6 to 2·0 m., corresponding respectively to a normal prototype discharge of 10 to 50 cu. m. per sec. The tests were well within the region of partial sediment transportation, as evidenced by the fact that the average diameter of material in motion was only one-third the diameter of the bed material which ranged in size from 3 to 500 mm.

The paper discusses briefly the experimental details and limitations, and presents the test results in the form of tables and a graph showing the comparative grain size distribution of the transported and bed materials. The results are also expressed in terms of a formula facilitating comparison with the formulae for full transportation, for which purpose the test section is divided into i vertical sections; this formula expresses the solid discharge as a function of diameter and local tractive force.

$$\begin{cases} g_i = A\,(d_i^{1/4} - d_o^{1/4})^4 \quad (\tau - \tau_o)^{3/2} & (1) \\ d_i = B\,\tau^4 & (2) \end{cases}$$

in which τ_o is the critical tractive force, d_o is the mean diameter computed from (2) under conditions of $\tau = \tau_o$ and, using metric units, $A = 7{\cdot}3 \times 10^4$ and $B = 17{\cdot}7 \times 10^8$.

After a comprehensive analysis of the results and the corresponding formula, the authors draw the following conclusions:—

(1) The experiments covered that range of partial transportation in which only the roughness of the bed material affects the transportation phenomena.
(2) The test results are valid only for steady phenomena of transportation and constitute merely a first step toward comprehending the natural phenomena.
(3) The objective has been to make available precise and controlled experimental data.
(4) Further investigation of partial transportation is essential for model studies.
(5) Knowledge of partial transportation phenomena would make possible in some cases indirect determination of solid discharge in natural watercourses by means of studies of grain size distribution of transported material under known hydraulic conditions.

A practical application of basic principles is to be found in a paper, "Some Factors Affecting the Stability of Canals Constructed in Coarse Granular Materials," by E. W. Lane and E. J. Carlson, of the U.S. Bureau of Reclamation. During the past three years, personnel of the Bureau have carried on studies to perfect methods for designing canals in coarse, non-cohesive materials. A number of stable canals were located in the San Luis Valley of southern Colorado that had been in use since the late 1800's. Hydraulic measurements were made on test sections selected from the San Luis Valley canals, and other observations and measurements were made on the bed and natural bank materials which formed the test sections. The canals studied were constructed in the alluvial cone deposited by the Rio Grande River on the floor of the San Luis Valley.

The equations of Strickler and Keulegan relating median size of bed material to Manning's n value, give values of n that are slightly lower than the average value determined for the San Luis Valley test sections. Irmay's equation relating maximum diameter and Manning's n gives a value for n slightly lower than the value for San Luis Valley test sections when the bed material size of which there is 10 per cent. larger by weight is plotted against Manning's n. The San Luis Valley tests have shown that Manning's n decreases as depth and velocity increase for a given channel and boundary conditions.

The use of limiting tractive force in designing canals in coarse, non-cohesive material results in definite advantages in that it makes possible more economic designs. The force necessary to cause movement of non-cohesive material on a sloping side of a channel is less than that required to cause motion of the same material on a level bed. The ratio of the force necessary to cause impending motion on a sloping side to that required on the level bed is shown to be a function only of the slope of the side and the angle of repose of the material.

Other papers dealing with sediment transportation included "Regime Theory Equations Applied to a Tidal River Estuary." by T. Blench, University of Alberta, Canada, "Basic Relationships of the Transportation of Solids in Pipes." by R. Durand, Laboratoire Dauphinois d'Hydraulique, France, and "Bed-Load Transportmeter for Fine Sand 'Sphinx'" by J. B. Vinckers, E. W. Bijker and J. B. Schijf, Rijkswaterstaat, Netherlands.

Questions of erosion and scour were covered by "Some Basic Requirements for Protection Against Erosion" by C. J. Posey, State University of Iowa, "A Generalised Model Study of Scour around Bridge Piers and Abutments" by Emmet M. Laursen and

Arthur Toch, State University of Iowa, "Mechanism of Erosion Below Hydraulic Works" by Nazir Ahmad, Irrigation Research Institute, Pakistan, "Experiments on Design and Behaviour of Spur Dykes" by Mushtaq Ahmad, Irrigation Research Institute, Pakistan, and "Scour from Jets," by Doddiah Doddiah, Maurice L. Albertson and Robert Thomas, Colorado Agricultural and Mechanical College.

Waves, Beach Erosion, and Shore Structures

This section lies somewhat outside our immediate purview as it is concerned mainly with marine works, and we must therefore content ourselves with publishing the list of papers, which are as follows: "Basic Experimental Wave Research" by F. Suquet and A. Wallet, Neyrpic Hydraulic Laboratory, France, "Investigation of the Effect of Resonant Structures on Wave Propagation" by J. Valembois, Laboratoire National D'Hydraulique, France, "Table Bay as an Oscillating Basin" by Basil W. Wilson, A. and M. College of Texas, "Wave Damping Effect of Beaches" by John J. Healy, Civil Engineer Corps, United States Navy, "The Influence of a Vertical Wall on a Beach in front of it" by R. C. H. Russell and Sir Claude Inglis, Department of Scientific and Industrial Research, England, "Beach Erosion in Japan" by Koichi Aki, Tokyo University, "The Effect of Waves on a Sand Beach" by Harold Flinsch, Mississippi State College, "Effect of Distortion on Sea-Hydraulic Models with Movable Bed" by Leon Levin and Michailo Voyinovic, Laboratoire d'Hydraulique d'Avala, Yugoslavia, "Design of Rock-fill Breakwaters" by Per Anders Hedar, Chalmers Tekniska Högskola, Sweden, "Experimental Study of Wave Overtopping on Shore Structures" by Thorndike Saville jun. and Joseph M. Caldwell, Beach Erosion Board, Department of the Army, United States, "The Wellawatte Canal Outlet in Ceylon" by T. Mylvaganam and W. E. Paranathala, Irrigation Department, Ceylon, "A Multi-Purpose Wave Generator" by Lt. C. B. Coyer, United States Navy, "A Continuous Recording Point Gauge for the Measurement of Surface Waves" by W. Douglas Baines and Ian D. Smith, National Research Council, Canada.

(To be continued)

Book Reviews

Annuaire de l'Association Suisse des Electriciens & Union des Centrales Suisses d'Electricité (Year-book of the Swiss Association of Electrical Engineers and Union of Swiss Power Plants), published as a special issue of the *Bulletin de l'Association Suisse des Electriciens*, Zurich. 8 in. × 11½ in., 126 pp.

This year-book contains, as usual, full information about the two Associations concerned, as well as a list of their publications, an extensive bibliography, and a directory of the Swiss federal, cantonal and regional offices and institutions connected in one way or another with power generation and electric industries.

Review of Current Research and Directory of Member Institutions. Engineering College Research Council of the American Society for Engineering Education. Obtainable from V. E. Neilly, Secretary, 103 Mechanical Engineering, The Pennsylvania State College, State College, Pennsylvania. 330 pp. Paper covers. Price $2.50.

This biennial publication lists the researches now in progress in all branches of engineering in all the major engineering colleges in the United States. The number of member institutions is 103, and the number of research projects listed is about 5,000. As is only to be expected in a catalogue of researches covering so many fields, the number of projects of hydro-electric interest is not large, but an excellent classified index gives ready reference to current projects on any desired subject.

"L'Energia Elettrica," Indice Generale 1924-1950 (General Index 1924-1950), published by Società Editrice Riviste Industrie Elettriche (SERIE), Milan, 8·2 in. by 11·5 in., 227 pp.

The importance of this well-known contemporary is underlined by the fact that it is the official journal of the Italian Association of energy distributors (ANIDEL) and the Federation of electricity undertakings (FENIEL). This general index covers all the articles published in the journal from its foundation in October 1924 to the end of 1950. It is divided into three sections:—

(1) Authors, whose names, listed in alphabetical orders, are followed by the titles of the articles in chronological order;

(2) Subjects, such as, to mention water-power development only, hydro-electric plants, hydraulics, hydrology, etc.; in this section, only the general subject is given in alphabetical order, and the articles are listed in chronological order, while the titles of foreign books or articles reviewed are reproduced in their original language;

(3) Geographical index of plants and installations, in which a simple and comprehensive system of abbreviations enables the reader to ascertain at a glance the type of the plant or installation and the nature of the article.

L'Energia Elettrica must be given full credit for the compilation and publication of this excellent index which should prove very useful as a reference book.

Conductor Accessories for High-Voltage Transmission Lines. The development of hydro-electric power is tending to depend more and more on the success with which distant sources of supply can be brought to centres of consumption, so that the work of the transmission engineers has become of decisive importance. With respect to this an exceedingly well produced brochure, published in English, has been received from the Salvi Company, of Milan, Italy, who have now operated in this highly specialised field for more than two decades and have earned a reputation for sound design coupled with the highest standards of precision engineering. This brochure is well illustrated and is both detailed and informative, and contains a particularly interesting account of the Salvi "59D" hydraulic jointing compressor for compression joints, dead ends and other accessories.

The sole representatives of the Salvi Company in the United Kingdom and the British Commonwealth are Ferrum (England) Limited, 43, Norfolk Street, London, W.C.2.

The Forçacava Hydro-Electric Scheme

By PROF. DR. TECHN. L. v. RABCEWICZ, Stockholm

The following article describes the work of excavation for a subterranean machine hall with the adjoining pressure shaft and access and discharge tunnels for the projected power plant at Forçacava, Brazil, with special reference to the working methods adopted in unstable rock. An article describing the scheme as a whole was published in our August issue.

PART THREE

Draught tubes

As shown in Fig. 4 the roof arches of the draught tubes extend over the discharge tunnel. Consequently, the construction of the draught tubes had to be carried out in conjunction with the corresponding part of the discharge tunnel. The geological conditions in the region of the tubes *2, 3* and *4* were less favourable, as the kaolinised zone also strikes through here. Because of the small distance between adjacent tubes and the relatively great height of the tubes a mutual effect of movement and loosening of rock had to be anticipated during the simultaneous excavation of adjacent tubes situated in the zones *K* and *m* (Fig. 16).

It must be borne in mind that the cross section of such a pillar, although it appears quite safe from the drawings, is considerably reduced by the inevitable overbreak and loosening up of its border zones. Nor is that part of it which is finally left very reliable on account of the steeply dipping joints and sliding planes. It is consequently necessary to reinforce the weakened rock pillars by enclosing them as quickly as possible in reinforced concrete, followed by carefully executed grouting.

But even in the sound rock to the east of Hm 0·60 it would not be advisable to excavate two adjacent draught tubes without prior concreting of the corresponding lower area of the north wall, between the bottom and elevation 95, owing to the steeply inclined stratification and risk of rockfall, which would even endanger the concrete wall situated above it.

Fig. 26. A rock fall in the horizontal section of the pressure shaft

In concluding the description of the machine hall, it might be expedient to consider whether some other method of construction would have been better suited to the conditions. It was first intended to proceed gradually with the excavation and concreting at three levels, from the top towards the bottom of the machine hall. This method would undoubtedly have reduced the difficulties encountered considerably and would probably have eliminated them to a great extent. As a result of reducing the height of the excavation to one-third, the danger of slides and deformation decreases approximately quadratically. And what seems to be even more important, the excavated surfaces would have been left uncovered during a much shorter period. Gravity, water pressure and swelling effects would consequently have had much shorter time to exert their destructive action. Unfortunately

Fig. 25. Horizontal portion of pressure shaft, showing steel arch supports

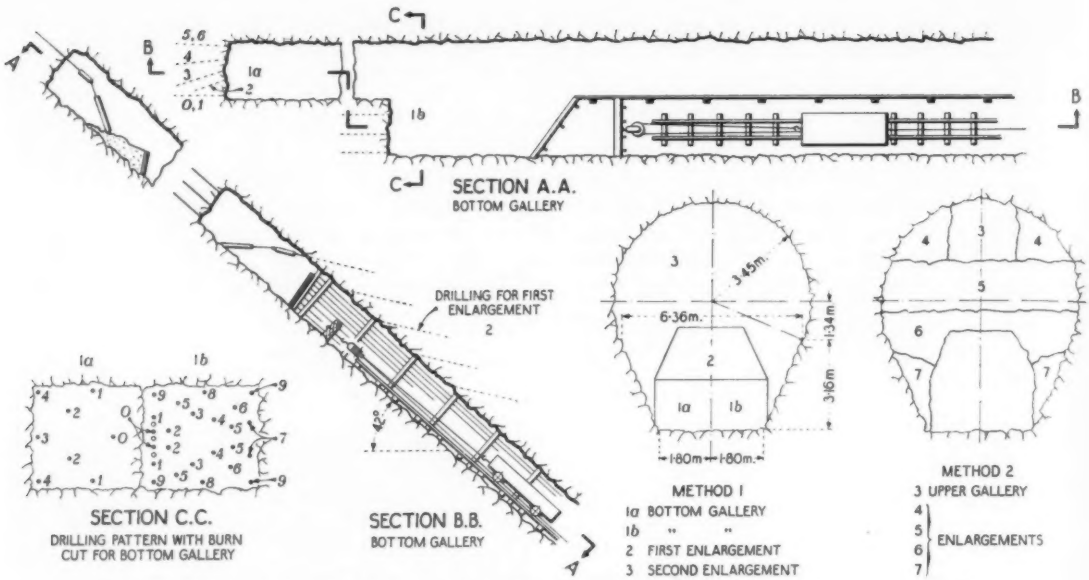


Fig. 27. Sections showing excavation methods employed in driving the pressure shaft

the intention to use this method could not be realised because at the time when the decision had to be taken the projecting work was not sufficiently advanced to allow the detailed shape of the concrete structures to be determined in time to permit their execution simultaneously with the excavation work.

Pressure Shaft

When driving the slightly inclined lower part of the pressure shaft, some difficulties were encountered when piercing the large fault zone, which in this immediate region was waterbearing to some extent. Rock conditions called for the immediate erection of steel supports, and even forepoling in some places (Figs. 25 and 26).

In the steeply inclined part of the pressure shaft a bottom heading was first driven, which was divided longitudinally into two parts by a wooden wall. It was found appropriate and economical to drive one part of the heading (*1 a*, Fig. 27) from 10 to 20 m. ahead of the second part, *1 b*. A wooden wall was erected just behind the face of part *1 b* to protect the transport track, this wall being extended in short sections so that the head of the track would always lie more or less close to the working face.

After the labourers had acquired sufficient training in the job, a

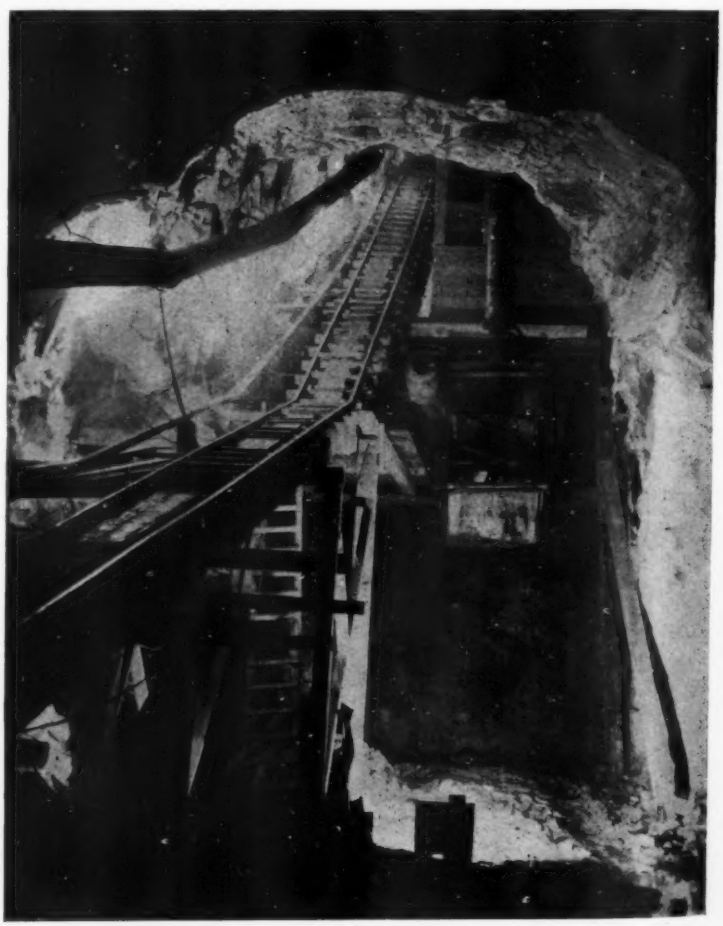


Fig. 28. Inside the pressure shaft showing rock chute and incline

Fig. 29. Pressure-shaft transport gallery

monthly advance of more than 100 m. was attained. The wooden separating wall was damaged repeatedly by falling blocks and so required constant maintenance. The dumping of the muck at the lower end of the pressure shaft by a pneumatically operated chute worked satisfactorily (Fig. 28). The driving of the bottom heading was carried out in accordance with the drilling pattern shown in Fig. 27, *C-C*. By using burn cuts a regular advance of 2 m. for each round was made (Fig. 27). Simultaneously with the driving of the bottom heading, the roof of the heading was drilled for a first enlargement of the superposed part of the rock, *2*, within the area of the pressure shaft. The blasting of this part, which proceeded from the machine hall upwards, was not started until the bottom heading had reached the valve chamber. Every round covered a length varying from 30 to 40 m., depending on the available number of stages of the electrical delay caps. Naturally, the wooden longitudinal separating wall had first to be removed along the corresponding length to be blasted.

For the further enlargement of the pressure shaft and the excavation of the remaining part, *3*, Fig. 27, a heavy drill jumbo was designed, the movement up and down the shaft being controlled by a winch placed outside the entrance to the approach tunnel of the valve chamber. The drill jumbo, weighing 13 tons, ran on a standard gauge track and had nine platforms at various levels, on which the drilling machines with pneumatic pushers worked (Figs. 30 and 31). Two additional machines drilled the lower holes to each side. The excavation of this part of the pressure shaft proceeded from the valve chamber downwards with the muck sliding down through the already completed bottom heading. After a somewhat delayed start owing to some minor initial difficulties with the jumbo and the training of the workmen, a monthly advance of more than 100 m. was achieved in enlarging the pressure shaft to full size. The sequence of operations and the corresponding times of one round are given in Table I. Further particulars relating to the pressure shaft are given in Table II.

The inclined pressure shaft traversed several fault zones, the worst of which was situated some 120-160 m. from the point *y* in Fig. 3. This zone consisted chiefly of a 2-3 m. wide crevice at the bottom filled with clay and shattered fragments of stone. This was followed by a layer of soft gneiss, which, near the solid rock at the roof, was intersected by another narrower crevice filled with clay. The strike of the crevice formed an angle of 30° with the axis of the pressure shaft with a nearly vertical dip, whereas the

Fig. 30. Drill jumbo and drill-hole pattern for enlargement of pressure shaft

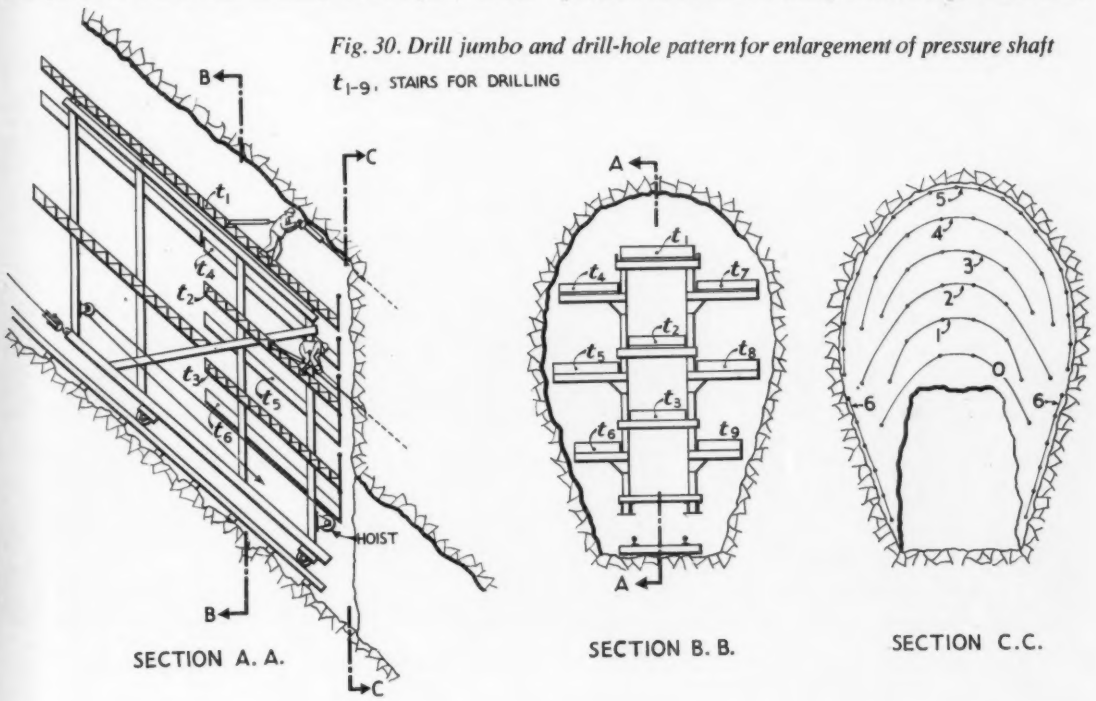


TABLE I

1	Clearing the bottom	0·5 hours
2	Relaying the first set of rails which had been removed prior to firing	1·5 „
3	Approaching the drill jumbo up to 4 m. from the face	0·5 „
4	Scaling down loose rock from the roof directly after blasting	1·0 „
5	Laying the second (lower) set of rails	2·0 „
6	Approaching the drill jumbo up to the face	0·5 „
7	Further careful scaling down of the roof and the face	2·5 „
8	Surveying and marking the drilling pattern	1·5 „
9	Drilling for the new round and for the protective netting	5·0 „
10	Charging and connecting the blasting wires	2·0 „
11	Removing the drill jumbo	0·5 „
12	Removing the last set of rails from the face	1·5 „
13	Firing and ventilation	1·5 „
14	Mealtime	1·5 „
15	Unforeseen contingencies	2·0 „
	Total	24·0 hours

foliation of the gneiss was almost vertical to the axis of the pressure shaft. Unfortunately, an additional joint dipping almost vertically and forming an angle of 10° with the axis, traversed the whole fault zone. The meeting of these two weak zones was, of course, a point which had to be treated very carefully.

With the exception of a part of the pressure shaft in excellent rock close to the valve chamber, the roof of the remaining part had to be secured by a wire netting attached to the rock by roof bolts. The netting was applied from the drill jumbo simultaneously with the drilling of the face. As a protection against falling rock from the lower part of the side walls, wooden walls were placed at intervals square to the axis, leaving sufficient free space for the track (Fig. 34).

In spite of all these precautions the work in the pressure shaft was very dangerous and tedious as it was necessary to proceed with the utmost care. Fortunately only few accidents occurred. Special protection was necessary in the zones of weaker rock and particularly in the broader fault zone. Fortunately, the rock remained standing without any major falls even in this fault zone during the short period that occurred between the blasting and the netting. It was originally intended to use steel arches for this part of the shaft, but the roof-bolting method proved successful even here and was much cheaper and quicker. In order to distribute the load on the roof bolts as uniformly as possible and to avoid any kind of movement, the bolts were connected to each other by steel channels running parallel to the axis of the shaft and firmly tightened to the rock by pneumatically wrenched nuts (Fig. 33).

Owing to the limited time available it was necessary to start the enlargement of the shaft from the lower end also (see method II, Fig. 27). After an upper heading, *3*, had been driven, it was extended laterally on both sides, *4*. Simultaneously with the application of the netting to the roof, the drilling and blasting of sections of the underlying slab, *5*, was carried out. This was followed by the excavation of the area, *6*. The blasting of this part, as well as that of the lower side parts, *7*, was not undertaken until the two enlargements had met, as the bottom heading was still required for the transport of muck from the upper

Fig. 31. The drill jumbo at the top of the inclined section of the pressure shaft

TABLE II

Cross section	1 a	1 b	2	3	Total
Area ..... sq. m.	4	3	5	32	44
Drill penetration per round ..... m.	2·4	4·8	2·8	4·8	
Advance per round ..... m.	2·0	4·5	2·6	4·0	
Number of drilled holes	25-27	8	6	60-63	
Number of workmen per shift of 8 hours (including electricians, mechanics, etc.)		18		45	
Consumption of explosives kg. / per sq. m.	5·7	1·9	1·5	1·25	

Fig. 32. View of completed excavation of pressure shaft

Fig. 34. Wooden bulkheads and roof bolting in pressure shaft

part. Method II was only practised for a distance of 75 m. and to have proceeded further with it would have necessitated uneconomic tracklaying (Fig. 35).

Mechanical Equipment of the Construction Site

Atlas-Diesel drilling machines on pushers, Type 656 W, were used for all the drilling work. The compressed air was produced by two Atlas-Diesel and two Ingersoll-Rand compressors with a total capacity of 53 cu. m. per min. For the enlargement of the pressure shaft an additional quantity of 30 cu. m. per min. was delivered by another plant. Mucking was handled by two Joy loaders, three 75 Conways and one Eimco 40. The two former types of machines were

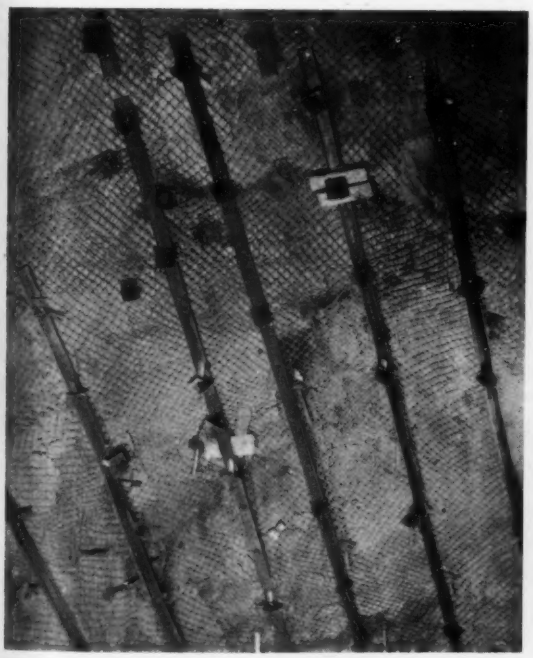


Fig. 33. Detail of roof bolting and netting for unstable rock

Fig. 35. View inside pressure shaft showing enlargement by method II

driven by electric motor. In the eastern part of the machine hall a P&H shovel with a capacity of 1½ cu. yards was employed and was later on replaced by a North-west shovel of 2½ cu. yards. Furthermore, a smaller Lima shovel with a capacity of ¾ cu. yard was working at times. The transport equipment consisted of ten Aveling Barford dumpers, each having a capacity of 4½ cu. yards, and eight Koehrings of 6 cu. yards capacity. For the transport problem, which had to deal with great differences in height over relatively short horizontal distances, the choice of trackless haulage was the only possible solution. The track-bound Conways were not so suitable for the work, although this fact did not occasion much trouble. Obviously a good deal of the equipment was held in reserve or was under repair. The concrete was generally placed by means of concrete guns, and vibrators were used for compacting.

Blasting Methods

Dynamite containing 30 and 60 per cent. of nitro-glycerine with electric ignition was used for blasting throughout. On several occasions trials were made with Bickford fuses and ordinary caps,

Fig. 36. Erection of steel pipes in the valve chamber

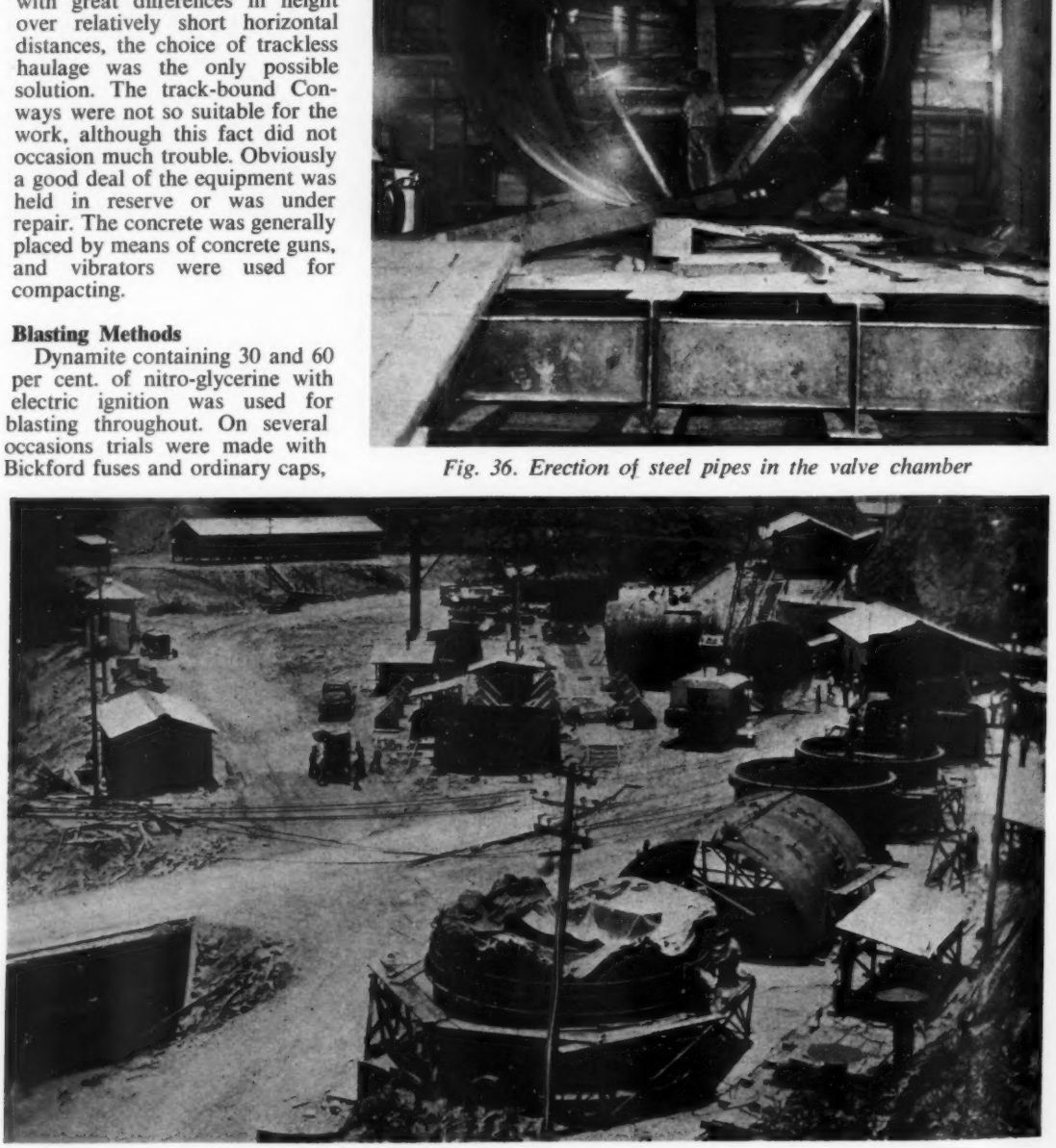


Fig. 37. Welding of steel pipe sections on the surface at Vigario

which, however, had to be abandoned as the quality of this material was too unreliable and the workmen refused to handle it.

Some rather interesting experience was gained in the field of technical blasting during the progress of the work. It was of course necessary to get the muck in a suitable size for the loading equipment. At the same time the shaking of the surrounding rock by heavy blasting had to be avoided in order to reduce excessive overbreak and to minimise the loosening movement. Under these circumstances the short-delay blasting method should have fulfilled the requirements in an ideal way, but was not practicable owing to the danger of rupturing the wires in the following row, with the consequent risk of having unexploded dynamite in the muck. American short-delay detonators with an interval of 0·025 sec. were therefore used, but in many cases it was obviously not possible to obtain the desired diminution of the shock. Apparently the delay time and the natural oscillation frequency of the rock waves were sometimes equal, or in such relation to one another as to multiply the amplitudes. In order to avoid the heavy shocks due to these effects it seems necessary to reduce to a certain minimum the quantity of dynamite ignited at any one time, having regard to the distance of the blast from the object endangered. The safest way would of course be to dispense with simultaneous firing and use normal interval blasting with either electrical or fuse ignition. Such a restriction to a single-shot system would have the important advantage of being easier to supervise and would also reduce to a considerable extent the disturbance to the equilibrium of the surrounding rock structure.

The effect of the shocks of the detonation waves on the adjacent parts of tunnels and underground excavations is still frequently underestimated, especially when excavation and concreting have to be carried on simultaneously. In the present case we had to deal with a hard rock which was sometimes intersected by huge zones of weak, partially plastic rock. Temporary and permanent concrete supports had to be erected close to portions of rock still to be blasted. There is no doubt that the shock effects of serial blasting contributed considerably to the difficulties described. When the great advantages of short-interval blasting are taken into consideration, it would be of great value to have some series of tests made with this method in order to determine the admissible quantities of explosives to be used under different rock conditions, having regard to the distance of the blast from concrete or masonry structures.

Acknowledgment

This article is published by kind permission of Brazilian Traction, Light and Power Co. Ltd., Toronto, in association with Companhia Brasileira Administradora de Serviços Técnicos, São Paulo.

Progress in Toronto

In accordance with the programme outlined in the 1951 report for the initiation of a municipal standardisation plan, the Toronto Electric Commissioners, in their latest report, state that the Hydro-Electric Power Commission of Ontario installed 60-cycle transformer and switching equipment at their Toronto-Wiltshire and Toronto-Thorncliffe terminal stations. This was in addition to 60-cycle equipment previously installed at Toronto-Strachan and Toronto-Gerrard terminal stations. With this terminal capacity established, the system was able to supply 13,200 V, 60-cycle service to twelve of its larger consumers so that they could begin conversion of their plants in advance of the general frequency standardisation programme.

The installation of a city-wide distribution system of 60-cycle supply at 120/240 V was also initiated during the year 1952. In an area of four square miles, the installation of the secondaries, together with the necessary 4,150 V primary feeders and transformers was three-quarters completed at a cost of $430,000. In addition, a considerable amount of work was undertaken outside the above area in order to supply 60-cycle service to 1,147 new consumers. The duplicate 60-cycle secondary programme, together with the supply of these new consumers, involves the installation of twenty 4,150 V primary feeders and 547 distribution transformers having a total capacity of 14,766 kVA.

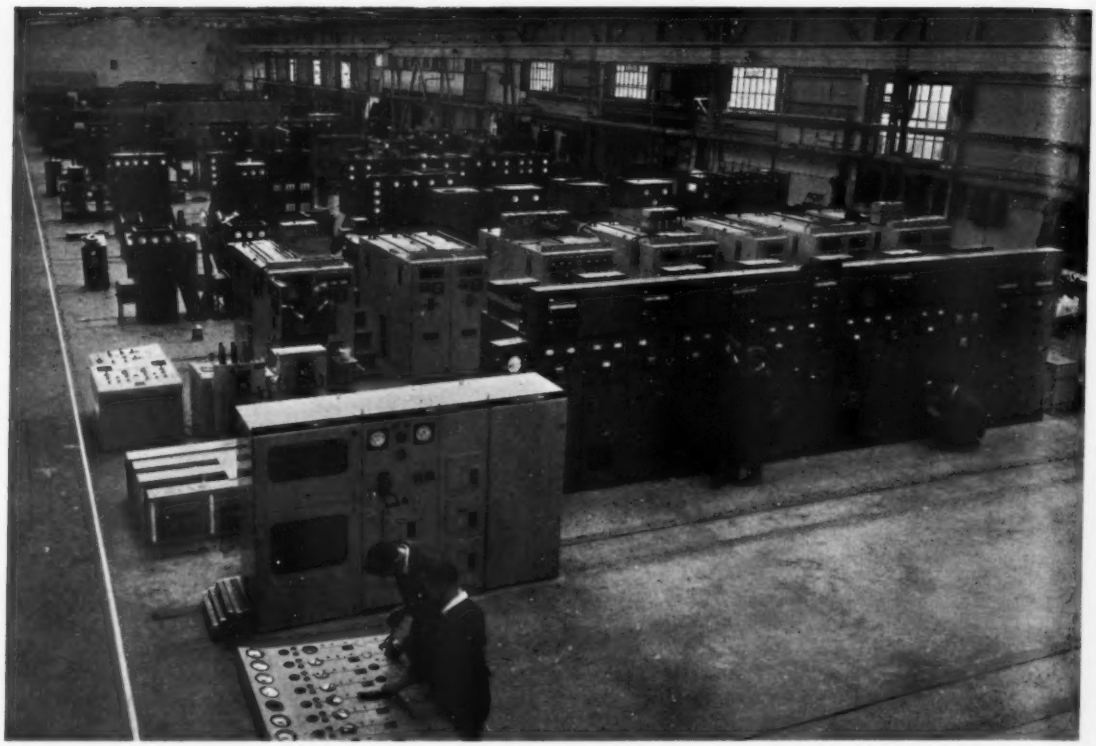
In Leaside, the Wicksteed 550 V substation was converted to 60-cycle operation for the supply of new loads in that area. In the central section of the city, fed from the low voltage network, a load of approximately 11,000 kVA was being supplied with 60-cycle energy by the end of the year. This involved the construction of seven vaults and the installation of 24 network transformer units. By the end of the year, the total load supplied in the area served by the system at 60 cycles amounted to 50,600 kW. Notification was received from the Hydro-Electric Power Commission of Ontario that the interim rate to be charged the Toronto Hydro-Electric System for power purchased would be increased to $38.75 per kW per annum as from January 1, 1953. While that represented an increase of 17·1 per cent. in the interim rate, it involved an increase of 19·1 per cent. over the net rate paid in 1952. The new interim rate as applied to the actual load bought in 1952 represented an increase of 2,516,157 dollars over the corresponding amount at the net rate paid in 1952.

The electrical energy purchased from The Hydro-Electric Power Commission of Ontario for the year 1952 cost $13,161,109.21 or 57·6 per cent. of the gross income, against $12,490,682.36 for the preceding year, or 57·4 per cent. of the gross income of that year. The interim rate was $33.10 per kilowatt per annum, and the monthly bills as rendered were paid for at this rate. After the close of the year's operations, the Provincial Commission advised that the cost of the power supplied was $228,749.87 less than had already been paid, and this brought the net cost to $13,161,109.21 or $32.53 per kW per annum.

With the authorisation of The Hydro-Electric Power Commission of Ontario, the Commissioners have appropriated from the net income of 1952 for the reserve for frequency standardisation the amount of $300,000, and for the reserve for non-revenue producing improvements to the plant of the system the amount of $950,000, and for the reserve for standardisation of voltage in the low voltage network area the amount of $480,000.

A table giving the physical growth of the system, which is published in the report, shows that at the end of 1912 the annual peak load was 12,830 kW compared with 443,355 kW at the end of 1952.

Brush Company's New Switchgear Factory



Erection bay for large switchboards in the new switchgear shop

A large proportion of the switchgear built at the Loughborough works of the Brush Electrical Engineering Co. Ltd. is of the metalclad type for voltages up to 15 kV and for breaking capacities up to 350 MVA. There are also under construction outdoor circuit-breakers for 33 kV services with a breaking capacity rating of 750 MVA. For low-voltage systems there is also a range of industrial pattern circuit-breakers and high-breaking-capacity fuse-switch gear, together with special control gear.

The manufacture of switchgear and control gear has recently been brought into a single-storey building having a floor area of approximately 150,000 sq. ft., to double the previous capacity for these products. This switchgear factory has been laid out to facilitate movement of materials, subassemblies, finished components and bought-out apparatus from a centrally positioned store to the erection bays disposed around it. The erection bay for large switchboards has an area of 41,000 sq. ft. and that for fuse-switch gear and control gear 15,000 sq. ft. Subassembly and fabrication sections account for about 56,000 sq. ft. Machining is carried out in central machine shops feeding all product divisions of the Loughborough works and is not accounted in the space quoted.

There are 29 switchboard building lines at 11 ft. centres to allow ample working space for assembly and manoeuvre for despatch. The lines will accommodate up to 25 ordinary panels. These switchboard building lines are for erection of the type of switchboard upon which there are many variables and the complexity of these will determine the time they are likely to occupy on the floor. Some types of switchboard, however, are made in large quantities and are highly standardised. They are erected on bogies running on floor rails with component parts drawn from containers alongside. Switchboards of this type can be in continuous flow production in contrast to other types. At the ends of the floor rails equipment is provided for electrical testing.

At one side of the fixed building lines is an area in which circuit breakers are assembled upon trucks for metalclad switch units prior to their incorporation in switchboards. In this area are master jigs for truck mounted circuit breakers and housings. The area set aside for production of circuit breakers and ancillary equipment is laid out for a logical sequence of operations to build from component parts to subassemblies and completed units.

Fabrication of the steel structures for metalclad switchgear and control cubicles is in a separate building adjacent to a covered stockyard for steel plates and sections. The majority of the structures are of welded construction and are standardised to a high degree. A multi-turret press in this shop accommodates 32 punches of different size and shape in a horizontally rotating head.

Electrical testing before despatch takes place in an

enclosure at the despatch end of the erection bays. A separate workshop is provided for development and research, and production control, progress and planning and foreman's offices are located along one side of the shops and do not intrude into the assembly areas.

During a recent visit to Loughborough to inspect the new factory we also had the opportunity to see the extensive research laboratories, now in process of further extension, and the transformer shop which has supplied many units for hydro-electric schemes and has a number of hydro-electric orders on hand.

Portable Jack for Prestressing Concrete

One of the most important advances of recent years in the design of reinforced-concrete structures has been the use of prestressing, but with certain systems

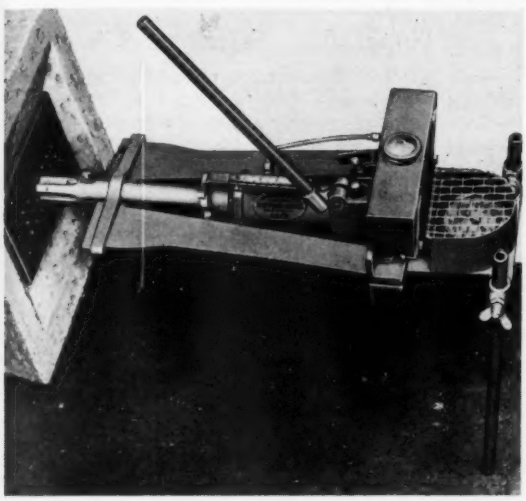


Fig. 1. Gifford-Udall-CCL prestressing jack

the heavy and costly jacks required have confined the technique to large schemes. A system designed to involve the minimum of capital and labour costs is now available from Cable Covers Limited, Prestressed Concrete Division, St. Stephen's House, Westminster, S.W.1, under the name of the Gifford-Udall-CCL Prestressing System. It is based on the principle of stressing each wire of a cable individually, with the result that the operation can be carried out by one man using a portable jack weighing only 56 lb. (Fig. 1). An individual wire can be stressed in about three minutes, and any size of wire up to 0·276 in. can be handled.

The system is equally suitable for post-tensioning, and for this procedure the wires are brought out to a mild-steel coverplate drilled to correspond.

The wires are anchored by grips of the type shown in Fig. 2, these grips being identical in principle with those widely supplied by Cable Covers Limited for joining lengths of overhead power cable and repairing breaks.

Fig. 2. CCL anchor grip

General Electric Company Schenectady

This year the General Electric Company of America is celebrating its 75th anniversary and in common with other great companies is devoting much attention to research. As an indication of the importance placed on basic research, Dr. C. G. Suits, vice-president of the company, announced recently that the staff at the research laboratory would be increased from 1,000 to 1,500, and 450 fully qualified scientists would be employed. The subjects investigated cover a very wide range and extend from weather research to iron-producing bacteria and from jet fighters to atom smashers. Our illustration shows Dr. Vincent J. Schaefer breathing into a freezing chamber as fellow scientists, Dr. Irving Langmuir (left) and Dr. Bernard Vonnegut, watch the formation of supercooled "cloud." Dropping dry ice into the freezer produced ice crystals. This is an important discovery in cloud-seeding technique to stimulate rainfall, which will be the subject of two articles which will shortly be published in this journal.

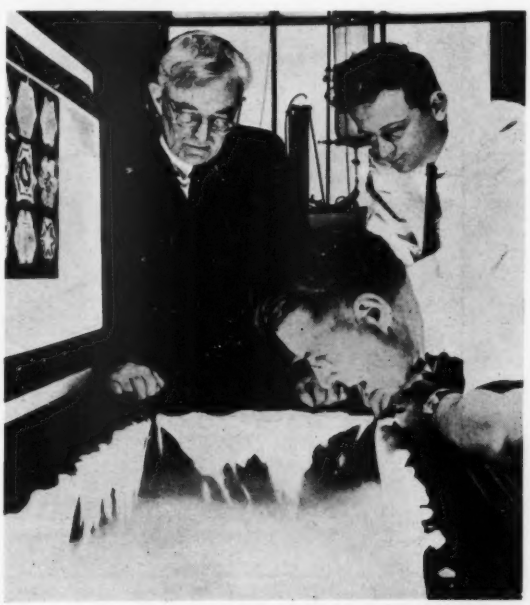


Fig. 1. Forming a supercooled "cloud"

Abstracts from the World Technical Press

Planina-Verd Project, Yugoslavia

A description is given of the Planina-Verd hydro-electric development, South-western Slovenia, projected with a view to utilising the waters of the Ljubljanica basin, and the natural head between the Planina Field and the Ljubljana Marsh. The main characteristics are:—

Installed discharge	62 cu. m. per s.
Gross head	177·25 m.
Net head	156·7 m.
Installed capacity	78·75 MW
Average yearly production	248 M kWh

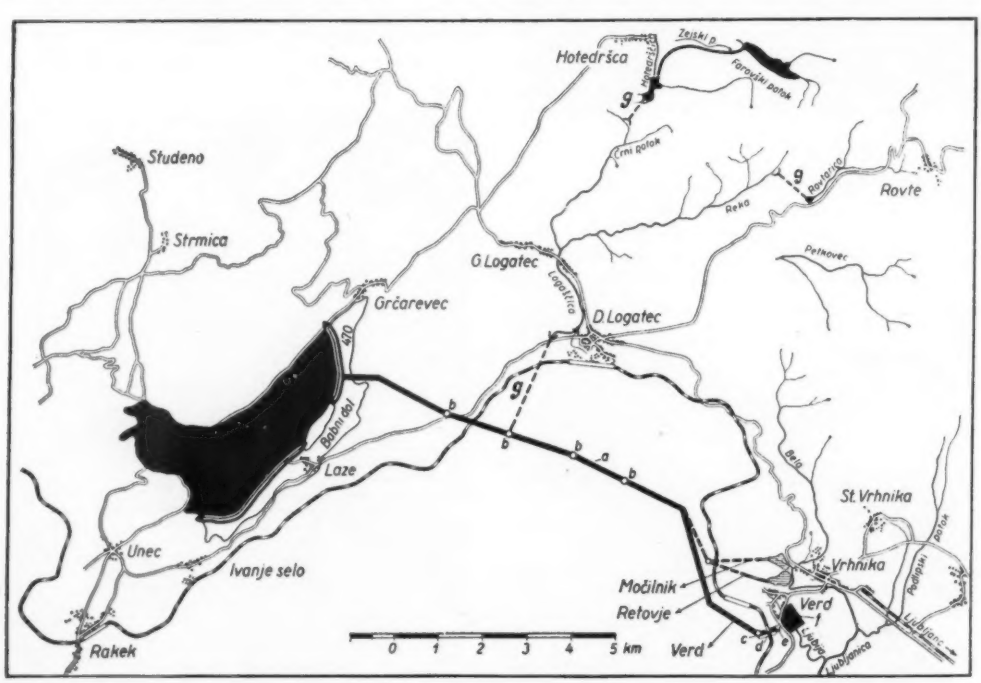
The appended map shows the general layout of the contemplated development. A dam at the south end of the Planina Field would create a storage reservoir varying in level between elevation 450 and 470 m.; the pressure tunnel, connecting with the reservoir through a bottom outlet, would have a length of about 11·7 km. between the foot of the dam and the surge tank to the north of Verd. If necessary, and economically justified, additional supplies of power water could be obtained by diverting the small rivers Hotenka and Rovtarica into tributaries of the Logascica, and connecting the latter north of Dolni Logatec direct with the pressure tunnel. Theoretically, the power house could be located at either Mocilnik, Retorje or Verd; the two first sites would shorten the pressure tunnel by about 2 km. but this advantage would be offset by penstocks exceeding 1 km. in length as well as by the fact that the power house would have to be set up within the territory where the Ljubljanica rises, so that excavation work for the foundations would meet with considerable difficulties. It appears therefore that, as shown in the map, the most favourable site would be Verd, where the power house could be built either underground or at the surface, with three generating sets and an outdoor switchyard in either alternative.

The tailrace would run into a compensating reservoir whose purpose would be to equalise the flow into the Ljubljanica so as to ensure the stability of its banks; in addition the bed of the Ljubija between the compensating reservoir and the Ljublanica would be corrected.

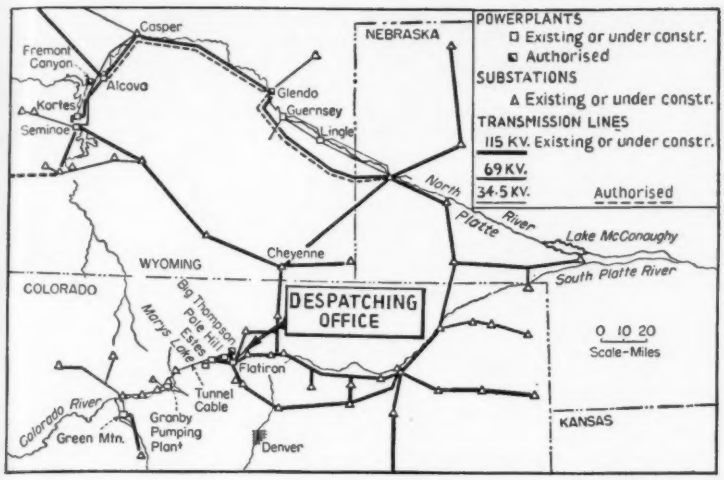
Once carried into effect, this project would provide the Slovenian districts of Yugoslavia with urgently needed winter energy. (Ing. Savo Janezic, *Elektrotehniski Vestnik*, Vol. 21, No. 5/6, May-June 1953, p. 122, 10 pp., 9 ff.)

Upper Platte System, U.S.A.

Water for a million farm acres and power for 130 wholesale customers benefits three states through canals and transmission lines controlled from a dispatching office located at Flatiron Mountain, some 50 miles north-west of Denver, Colorado. From this new control station flow the orders for delivery of water and power from Colorado—Big Thompson and the Upper Platte System into Colorado, Wyoming and Nebraska. Flow of water through turbines at six power plants, and flow of electricity through sub-stations over 2,500 miles of high-voltage transmission lines are involved. Sixteen major reservoirs, operated through Flatiron control station, hold a total of



a, Pressure tunnel; b, Adits; c, Surge tank; d, Penstocks; e, Power house; f, Compensating reservoir; g, Additional intakes



3,286,000 acre-ft. of water, and eleven power plants have an installed capacity of 288,300 kW. The control station is housed in a T-shaped building with administrative offices in its stem and a two-storey control room in the cross of the T. The main feature of the latter is a semi-circular, 10 ft. high control board on which the entire power system with all its plants, substations, significant switching points and interconnections with other systems, are diagrammed. Instruments record all operating conditions and data needed by the dispatchers who staff the station around the clock. (*Engineering News-Record*, Vol. 150, No. 23, June 4, 1953, p. 38, 2 pp., 5 ff.)

Safety Brake for Kemano Ropeway

To serve the construction at Kemano a huge aerial tramway has been built to carry 20 tons of freight or 60 passengers about a mile up the side of Portal Mountain to an elevation of 2,600 ft. The total weight of haul is 32 tons. To guard against accident in the unlikely event of breakage of the $1\frac{3}{8}$ in. steel tow rope it was decided to fit an automatic emergency brake.

The first design, which was intended to brake on the two track strands, had to be abandoned because it involved the problem of "skipping" over the supports at the towers and because the clearances to be allowed for when the carriage rollers passed over the tower rockers were unduly large. In addition, there were the questions of limiting the deceleration of the car and the total stresses on the track ropes to safe values.

These difficulties were circumvented by equipping the ropeway with two further $1\frac{1}{8}$ in. ropes for braking only. Detailed calculations showed that provided that the ropes were carried 300 ft. up the mountain beyond the upper terminus they would stretch sufficiently on a full brake application to afford a practical rate of retardation without resort to a slow-braking device. It was therefore possible to design the brake shoes for immediate seizure. Further, it was possible to adopt a close clearance for the brake shoes, the movement being only five thirty-seconds of an inch per shoe, or a five-sixteenths nip. The braking ropes are carried on wooden shoes on the towers, and are trained into the brake shoes by guide pulleys on the trolley carriage. They are anchored at the top end by a system of equalising sheaves.

A detail of the brake-shoe actuating mechanism is given in Fig. 1. The power for actuating the brake pincers is supplied by a powerful spring which imparts travel to a slide engaging a pair of cams which force the free ends of the pincers apart. Normally the spring is held back by the oil pressure in a hydraulic cylinder

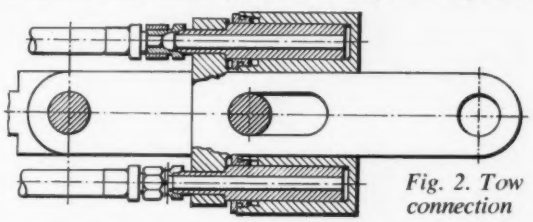


Fig. 2. Tow connection

connected to a hydraulic cylinder on the towbar (Fig. 2), but in the event of tow-rope breakage this pressure is destroyed and the spring is free to function. This hydraulic system possesses several advantages in addition to that of simplicity, for it ensures that the two brake gears, one on either side of the trolley, operate simultaneously, and it enables the brake to be applied from the car by a hand valve.

The braking system has been thoroughly tested, and a certificate issued by the Department of Railways authorising the operation of the aerial tramway. (Denis Critoph, *The British Columbia Professional Engineer*, June 1953, p. 31, 3 pp., 3 ff.)

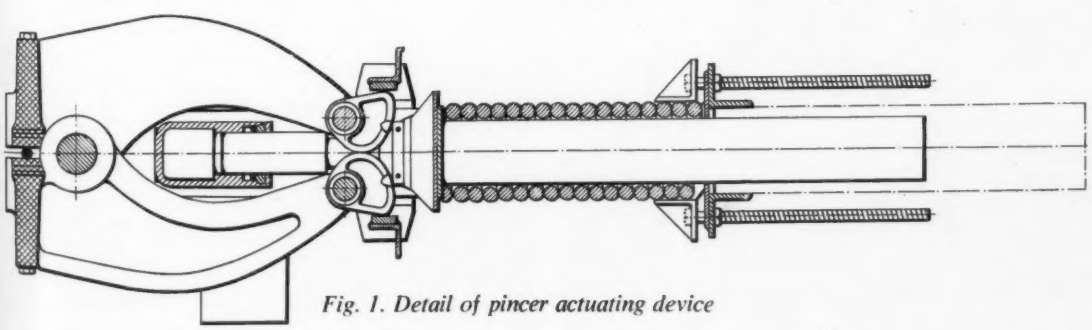


Fig. 1. Detail of pincer actuating device

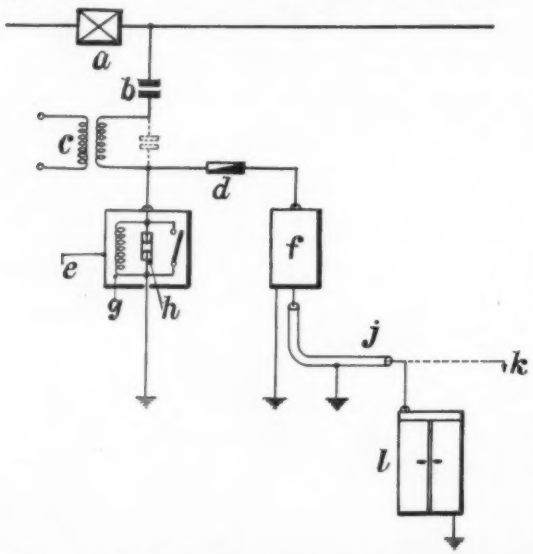
Harsprånget 380 kV Transmission

This issue is devoted entirely to two articles on electrical equipment for the 380 kV system bringing power from Harsprånget to the south of Sweden. The first deals with the design and testing of the step-up transformers at Harsprånget, the Midskog transformers, the Hallsberg transformers, the 400 kV bushings, the regulating transformers and the load reactors. The second article describes the design, manufacture, installation and testing of the cable connecting the underground transformers with the switchyard. ("The Transformers for the Swedish 380 kV Network," E. Stenkvist, and "The First 380 kV Power Cable in Sweden," by B. Hansson, B. Bjurström, R. Johansson and G. Axelsson. *ASEA Journal*. May-June 1953.)

Telecommunications in Grid Systems

This paper, which deals with some aspects of telecommunication techniques as applied to dispatching in grid systems, was read on March 20, 1952, at a meeting of the Association of Electrical Engineers trained at the "Institut Electrotechnique Montefiore" (A.I.M.) in Liege. The lecturer first discusses the advantages and disadvantages of the various propagation media intervening in telecommunications: telephonic overhead lines and underground cables, HT transmission lines, and ultra-short radio-waves. HT transmission lines are, like telephonic overhead lines, subject to atmospheric disturbances but the stability of their construction, as well as their high degree of insulation, are very valuable assets in telecommunications. In addition, owing to the wide range of the band of transmissible frequencies, several telephonic or telegraphic connections can be effected simultaneously on the same line. Telecommunication by ultra-short waves is a recent innovation in interconnected electric systems, and appears to be particularly advantageous in countries like Belgium, where connecting lines are relatively restricted in length.

Various aspects of telecommunication techniques, together with the equipment involved, are then reviewed: telephony, telemetering, telesignals, remote control. The lecture concludes with a short description of the telecommunication equipment manufactured by the "Ateliers de Construction de Charleroi." (Jean Maxence, Divisional Head, Telecommunication Department of the Ateliers de Constructions Electriques de Charleroi, *Bulletin Scientifique A.I.M.*, Vol. 66, No. 4, April 1953, p. 267, 34 pp., 23 ff.)



a, Wave trap; b, Coupling capacitor; c, Current transformer; d, Fuse; e, Protective gear; f, Matching unit; g, Discharge coil; h, Lightning arrester; j, Concentric cable; k, To other H.F. control cabinets; l, H.F. control cabinet

Automatic Power Plants

The essential characteristics of automatic power plants are briefly reviewed. Automatic plants can be classified in accordance with either the extent to which automatism is applied or the type of machines involved; the author follows the latter classification, dividing the plants into synchronous and asynchronous power stations, and discusses for each class the automatic control of starting, load regulation and protection, together with its possibilities of application and its principal advantages. In his conclusions, the author states that, in Italy, full automatic control has so far been applied almost exclusively to hydro-electric plants. In large plants, where safety in operation and quick working of controls are of the utmost importance, automatism, coupled with the incorporation of the most reliable protection systems, has been extended to whole cycles of control; in small and medium-size plants, full automatic control is spreading, since it permits substantial economies to be achieved, and asynchronous plants are the rule. Ing. Pezzoli, *Tecnica Italiana*, New Series, Vol. VIII, No. 3, p. 171, 5 pp., 7 ff.)

CLASSIFIED ADVERTISEMENTS

Announcements for this column can be accepted up to the 8th of the month for the following month's issue. The charges are fourpence per word with a minimum of 10s. Box No. facilities 2s. 6d. extra. In order to avoid accountancy it would be appreciated if instructions to insert were accompanied with remittance.

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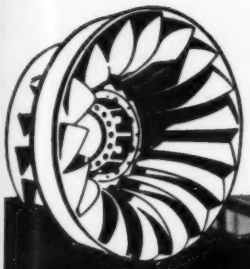

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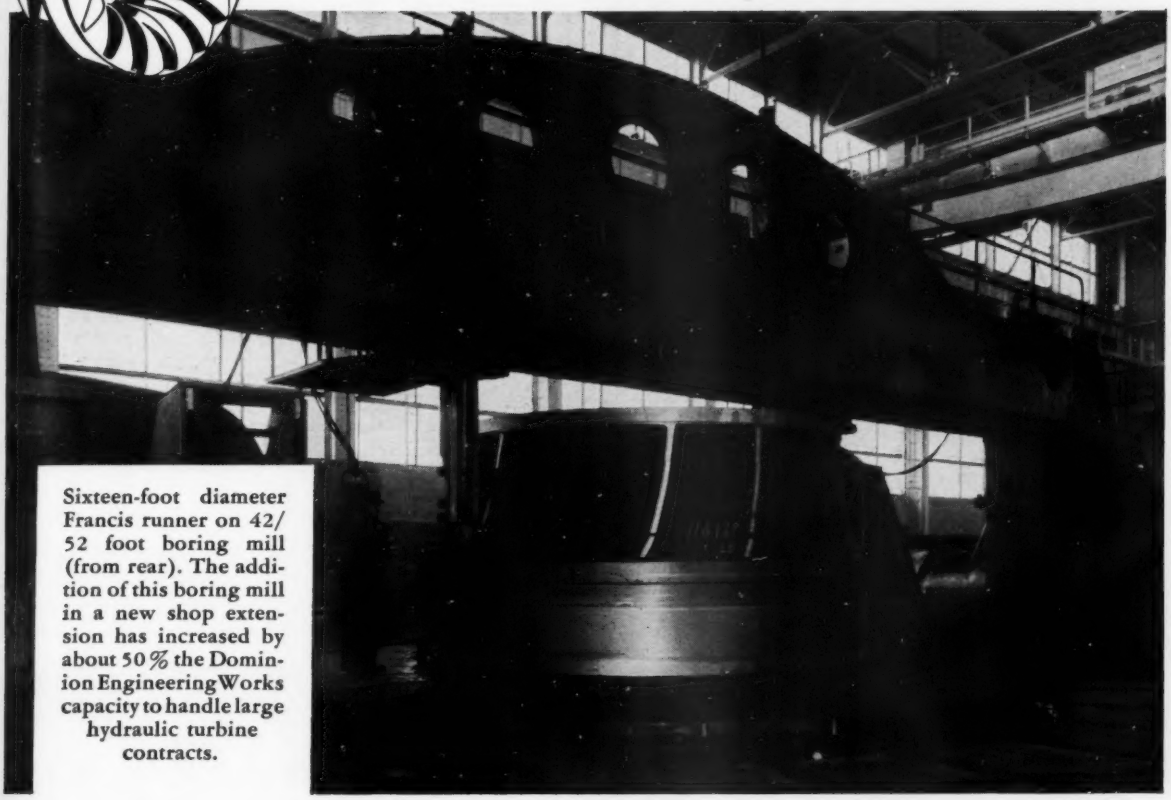

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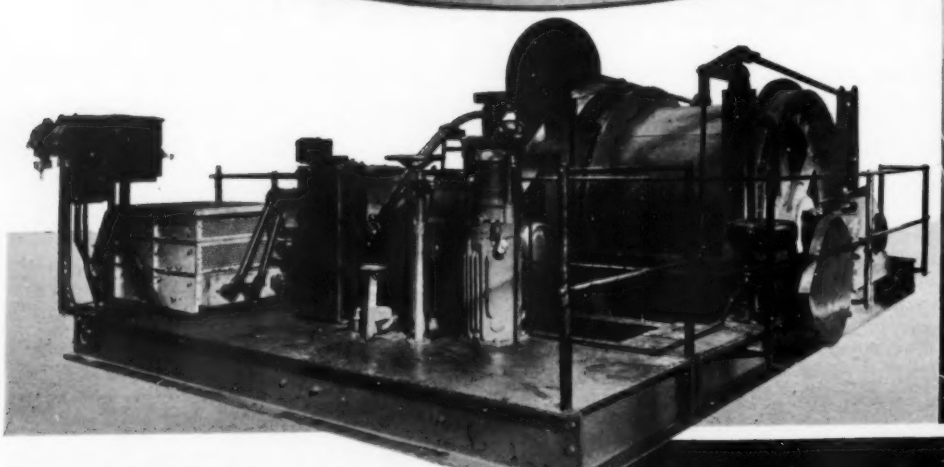

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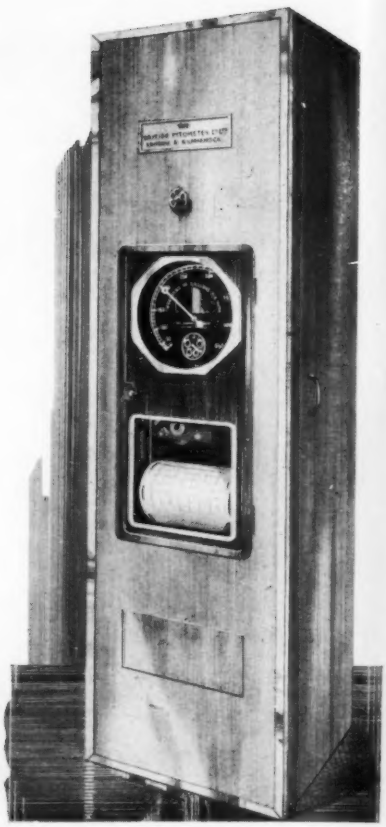

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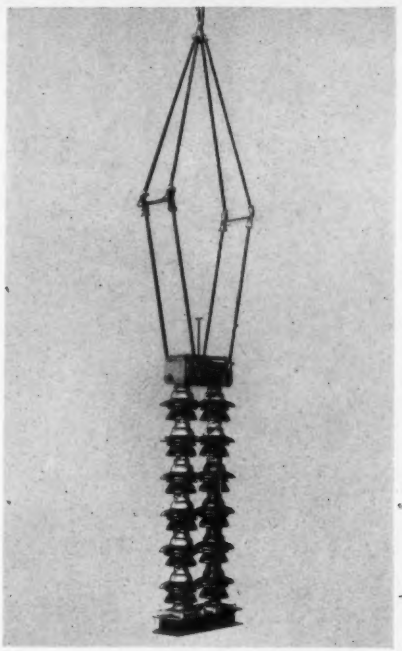

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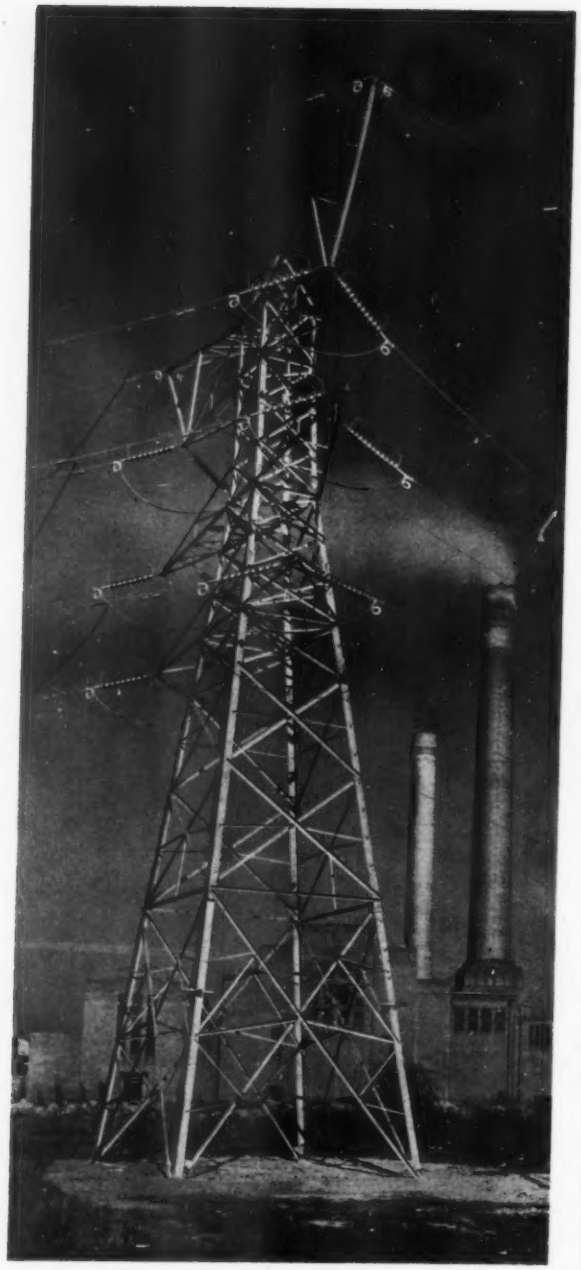

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View of pipeline and power house from the beach at Storr Lochs.

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INDEX TO ADVERTISEMENTS

A

Acciaieria E Tubificio Di Brescia ... ... —
Allgemeine Elektricitats Gesellschaft ... —
Allis-Chalmers 20
Allmanna Svenska Electriska Aktiebolaget ... 9
Aluminium Wire & Cable Co. Ltd. ... ... —
Anderson-Grice Co. Ltd. 54
Ansaldo, San Giorgio, S.p.A. 24
Armfield Hydraulic Engineering Co. Ltd., The —
Arrol, Sir Wm. & Co. Ltd. 32
Ateliers de Constructions Electriques de Charleroi ... ... —
Ateliers de Constructions Electriques de Delle —
Aveling-Barford Ltd. ... ... —

B

Balfour, Beatty & Co. Ltd. ... ... —
Bell, Theodore, Ltd. 42
Billington & Newton Ltd. 38
Birkett, T. M. & Sons Ltd. 38
Blackwood Hodge 17
Blakeborough, J. & Sons Ltd. 16
Blaw Knox Ltd. ... ... —
Boving & Co. Ltd. 5
Brady, G. & Co. Ltd. 41
British Insulated Callender's Cables Ltd. ... 52
British Pitometer, The, Co. Ltd. 56
British Ropeway Engineering Co. Ltd. ... —
British Thomson-Houston Co. Ltd. 6
Brown, Boveri & Co. Ltd. 35
Bruce, Peebles & Co. Ltd. 37
Brush Electrical Engineering Co. Ltd. ... 30
Butters Bros. & Co. Ltd. 28

C

Canadian Vickers Ltd. ... ... —
Cementation Co. Ltd. ... ... —
Ceretti & Tanfani Ropeway Co. Ltd. ... 43
Charmilles Engineering Works Ltd. 36
Consolidated Pneumatic Tool Co. Ltd. ... 15
Costain, Richard, Ltd. ... *Inside Back Cover*

D

De Roll, Louis, Iron Works Ltd. 3
Distington Enginering Co. Ltd. 26
Dominion Engineering Co. Ltd. 53

E

Eimco (Gt. Britain) Ltd. ... ... —
English Electric Co. Ltd. ... *Back Cover*
Escher Wyss Ltd. 39
Expandite Ltd. 49

F

Ferguson Pailin Ltd. ... ... —
Ferranti Ltd. ... ... —
Ferrum (England) Ltd. ... ... —

G

Galileo Officine, di Battaglia Terme ... ... —
General Electric Co., International ... ... —
General Electric Co. Ltd. 55
Gilbert Gilkes & Gordon Ltd. 25
Glenfield & Kennedy Ltd. ... ... —

H

Hackbridge & Hewittic Electric Co. Ltd. ... —
Harland Engineering Co. Ltd., The 50
Henderson, John M. & Co. Ltd. 22
Henley's, W. T., Telegraph Works Co. Ltd. ... 45
Holman Bros. Ltd. ... ... 10 & 11

I

International Engineering Co., Inc. 40

K

Karlstads Mekaniska Werkstad 44

L

Leffel, James & Company, The 47

M

Mannesmann-Export, G.m.b.H. 7
Marelli, Ercole & Co., S.p.A. ... ... —
Mechans Ltd. 59
Metropolitan-Vickers Electrical Co. Ltd. *Front Cover*
Michell Bearings Ltd. 58
Mitchell Engineering Ltd. ... ... —

N

Newport News Shipbuilding & Dry Dock Co. 8
Nuttall Edmund Sons & Co. (London) Ltd. —
Nydqvist & Holm Akt. ... ... —

O

Olding, Jack (Onions) Ltd. 34
Oerlikon Engineering Company ... ... —

P

Painter Bros. Ltd. 33
Pilkington Bros. Ltd. 21
Pirelli-General Cable Works Ltd. 46

R

Ransomes & Rapier Ltd. ... ... —
Rawlplug Co. Ltd., The 57
Reyrolle, A. & Co. Ltd. *Inside Front Cover*
Riva Costruzioni Meccaniche 13

S

SACE Costruzioni Elettromecaniche ... —
Salvi, A., & Company 12
Scarpa & Magnano 57
Smith, Fredk. & Co. 59
Smith, S. Morgan, Company 19
Smith, Thos. & Sons (Rodley) Ltd. ... ... —
Societa Anonima Elettrificazione, S.p.A. ... 4
Societa Condotte Forzate ... ... —
South Durham Steel & Iron Co. Ltd. ... —
Standard Telephones & Cables Ltd. ... ... —
Steatite & Porcelain Products Ltd. 27
Storey, Thos. (Engineers) Ltd. 18
Svenska Entreprenad A/B 31

T

Taylor, Tunnicliff & Co. Ltd. ... ... —
Tees Side Bridge & Engineering Works Ltd., The 58
Tosi Franco, S.p.A. 14

V

Vevey Engineering Works Ltd. 29
Voith, J. M., G.m.b.H. 23

W

Ward, Thos. W., Ltd. ... ... —
Westinghouse Electric International Co. ... —
Wild, M. B. & Co. Ltd. 54
Wood, Hugh & Co. Ltd. 48

Y

Yorkshire Electric Transformer Co. Ltd. ... —

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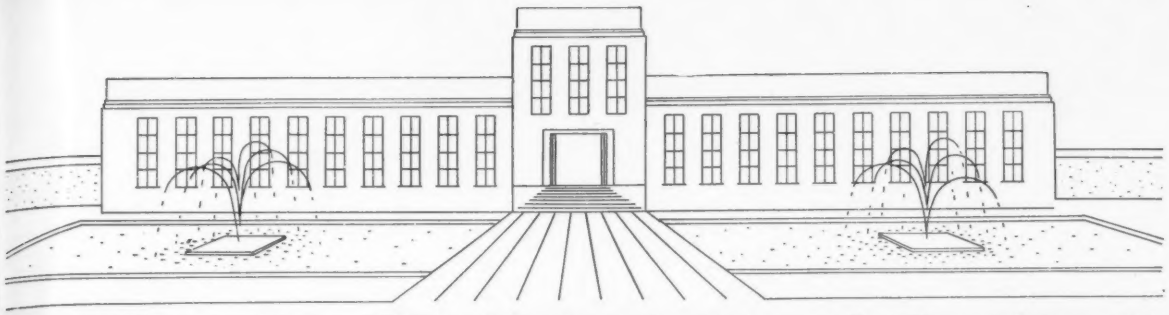

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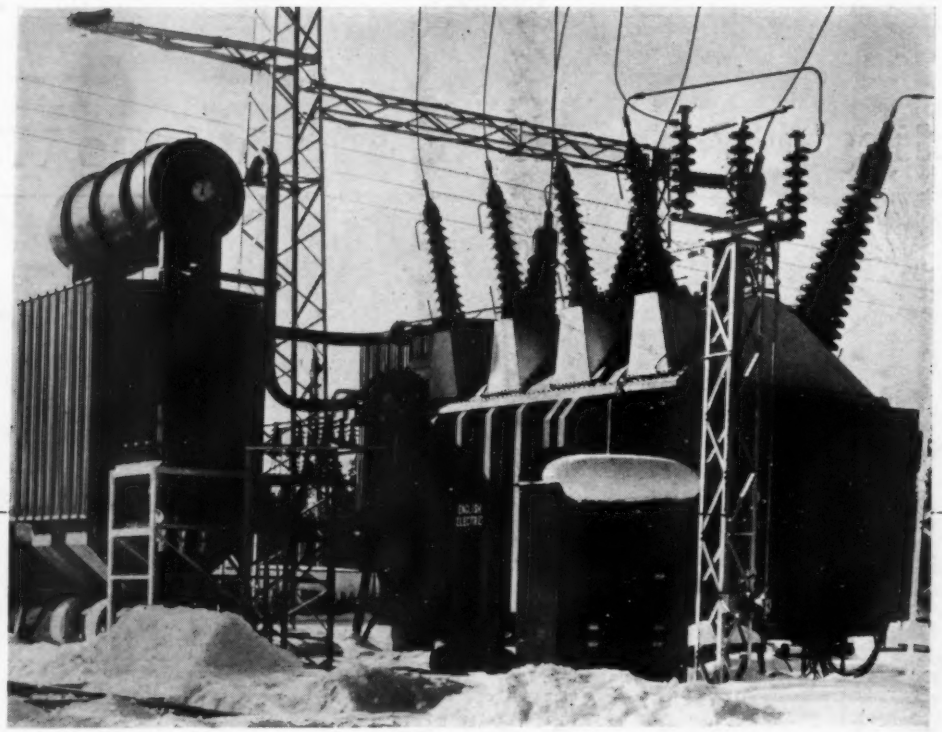

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